Bow River - MD of Bighorn Flood Risk Mapping Study

Submitted to
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River Engineering Branch
for
Canada - Alberta
Flood Damage Reduction Program

Bow River - MD of Bighorn Flood Risk Mapping Study

Report

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Executive Summary

The Bow River - MD of Bighorn Flood Risk Mapping Study was conducted as part of the Canada-Alberta Flood Damage Reduction Program to prepare flood risk maps for a 15 kilometer reach of the Bow River extending from Dead Man Flat to the western boundary of Bow Valley Provincial Park. Also included in the study is a 1 kilometer reach of Exshaw Creek immediately upstream of its confluence with the Bow River.

Open-water flood profiles were calculated using the HEC-2 backwater model developed by the U.S. Army Corps of Engineers. For the Bow River reach, the model was calibrated using measurements on the 1986 and 1990 flood events. No flood records were available on Exshaw Creek. Model sensitivity studies were undertaken and the results indicated that the HEC-2 program can be used with confidence to predict water levels for both reaches.

Flood risk and floodway boundaries were determined in accordance with the 1990 guidelines of the Canada-Alberta Flood Damage Reduction Program. These boundaries were presented on 1:5,000 scale orthophoto mosaics with topographic overlay showing contours at one metre intervals.

The maps indicate that, during a 100 year return period flood, a few buildings in the Exshaw Industrial Park would be inundated to a depth of about 0.5 meters. All three overland transportation routes through the Bow River valley would be subject to shallow inundation.

The calculated water levels on Exshaw Creek for the 100 year return period flood were all within banks. However, this steep stream is subject to erosion and sediment deposition during floods. Also, debris could quite easily block the rather small bridge openings on Exshaw Creek. Either of these possibilities could cause flood waters to overtop the banks.

Acknowledgements

The Bow River - MD of Bighorn Flood Risk Mapping Study was managed by Mr. Terry Winhold of Alberta Environmental Protection who defined the project criteria, supplied data and provided overall direction.

Other assistance and information were provided by the following individuals and agencies:

- Alberta Transportation and Utilities
- TransAlta Utilities
- Water Survey of Canada
- Mr. Kent Berg, Alberta Environmental Protection
- Mr. Ron Baker, Director of Operations, MD of Bighorn No. 8
- Glenbow Museum
- Mr. Ross Laurson, LaFarge Exshaw Plant

Acres is pleased to acknowledge the help of all the above noted individuals and agencies.

1 Introduction

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1.1 Flood Damage Reduction Program

The Canada-Alberta Flood Damage Reduction Program was established to reduce flood damages by applying a program that would identify areas subject to flooding and encouraging non-structural solutions such as land use planning, zoning, flood proofing, and flood preparedness.

Alberta Environment (1990) defines the flood damage reduction program as having the following components:

1. Identify, map, and designate flood risk areas in urban communities across the province.

2. Increase awareness of the flood risk among the public, industry, and government agencies through a public information program.

3. Regulate new development in flood risk areas using new federal and provincial government policies.

4. Encourage municipalities to develop zoning bylaws recognizing the designated flood risk areas.

Due to the increasing interest in urban development of the Bow River valley in the scenic Rocky Mountains the flood risk areas needed to be identified for future developers. As part of the Canada-Alberta Flood Damage Reduction Program, the River Engineering Branch of Alberta Environmental Protection commissioned Acres International Limited to undertake this Bow River - M.D. of Bighorn Flood Risk Mapping study.

1.2 Study Objectives

The purpose of this study is to identify and map the Bow River flood risk areas from the west boundary of Bow Valley Provincial Park to the Dead Man Flat development. The reach of Exshaw Creek which traverses through the Town of Exshaw is also included in this study.

The specific objectives of this study are to:

- Conduct a review of the history of flooding in the Town of Exshaw;
- Conduct hydraulic analysis and calculate open-water flood levels for various return periods of floods for the Bow River and Exshaw Creek;
- Delineate the flood risk boundaries and floodway limits for the 100 year flood event for the Bow River and Exshaw Creek;
- Prepare flood frequency maps showing the flood risk boundaries for the 10, 50, and 100 year flood events on the Bow River and the 100 year flood on Exshaw Creek.

The above information will furnish government agencies and developers with the basic data required for management and proper development of the Bow River and Exshaw Creek floodplains in the M.D. of Bighorn.

Investigation of flooding from high groundwater levels is not included in this study.

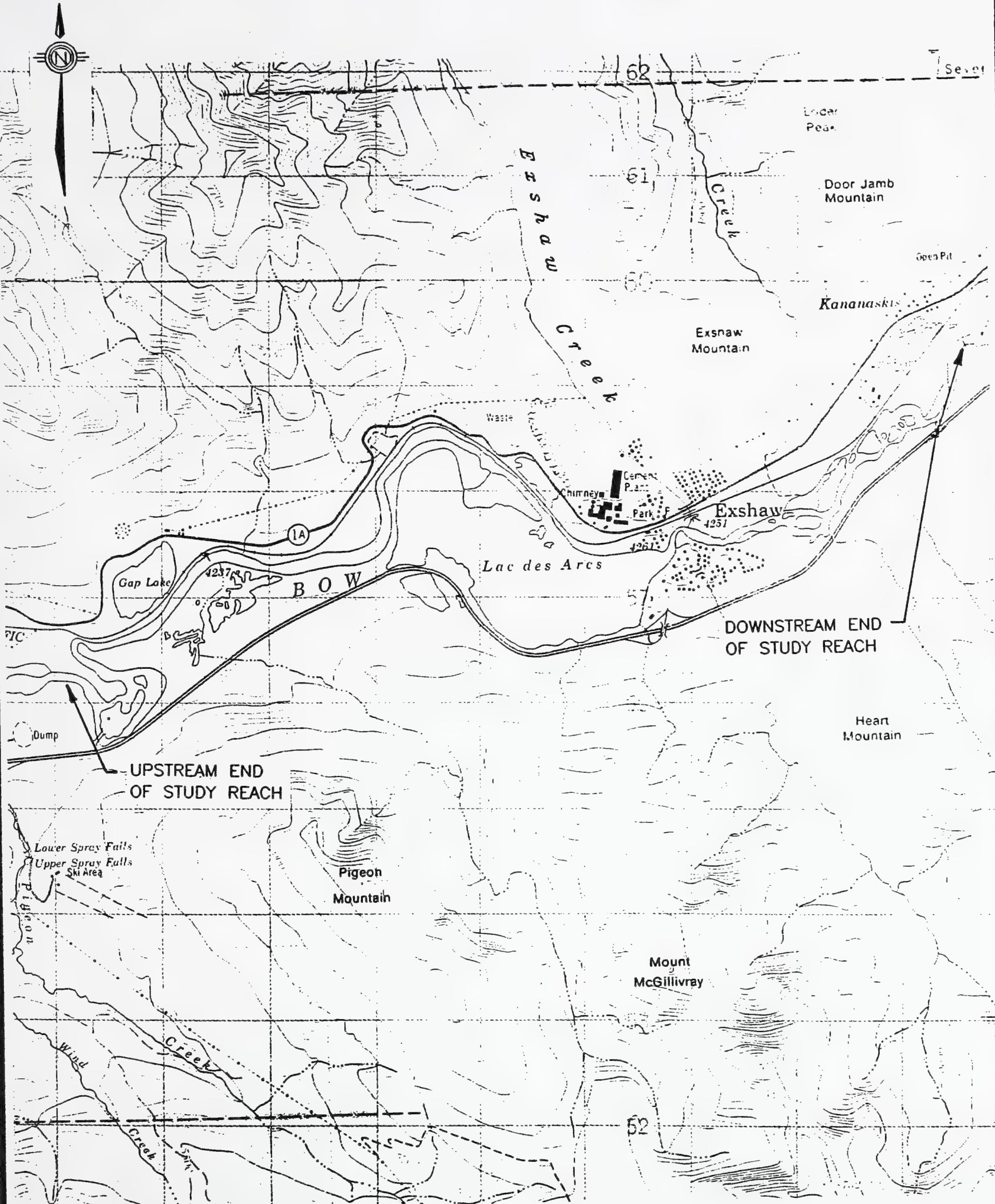
1.3 Study Area

Figure 1-1 illustrates the study area. It includes a 15 kilometre reach of the Bow River from the west boundary of Bow Valley Provincial Park to the Dead Man Flat development. The Exshaw Creek study area covers the 1 kilometre reach extending upstream from its confluence with the Bow River.

Limited development has occurred in the Bow River study reach. This reach does not contain any bridge crossings and the only features that affect the river are the recently built dykes that separate the main river channel from Lac des Arcs and the Canadian Pacific Railway (CPR) tracks that parallels the river.

The Bow River exhibits the characteristics of a braided river with split sub-channels, high water channels on the floodplain, and the occasional oxbow. Several small tributary streams flow into the Bow River in the study reach. Exshaw Creek is the only tributary that contributes any substantial flow.

Exshaw Creek is a steep mountain stream that passes through the Town of Exshaw. Five bridges cross the creek. Two are pedestrian crossings in the upper reach that are far above the creek bed. The other three, located at the downstream end of Exshaw



Location Plan Of Study Area

Figure 1-1

Source: Alberta Map 82 O/3

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Creek, are Highway 1A, the Canadian Pacific Railway, and an access road to the Exshaw Industrial Park. These bridge crossings are not very high above the creek bed. The creek carries a large amount of bed load gravels during high flows which tend to deposit in the area of the three lower bridges. Regular removal of bed material is required to maintain a clear channel under the bridges.

The land use and development in the study area include:

- Recreation areas at Lac des Arcs.
- Residential and industrial areas.
- Undeveloped Areas.

Residential and industrial areas are concentrated in the vicinity of Exshaw and Lac des Arcs. Upstream and downstream, the land is generally undeveloped.

2 History of Flooding

2 History of Flooding

2.1 Flooding on the Bow River

The Bow River basin is located in southwestern Alberta. The headwaters of the Bow River are located in the Rocky Mountains at Bow Lake just below the Bow Glacier. From its origin the river flows southeast past the communities of Lake Louise, Banff, and Canmore. The river traverses east through the study reach and then flows towards the City of Calgary. At Calgary, the Bow River heads in a southeasterly direction and joins with the Oldman River near the City of Medicine Hat to form the South Saskatchewan River.

The basin upstream of M.D. of Bighorn is mountainous terrain with thick forestation below the treeline (about 2100 m elevation). The total drainage area above M.D. of Bighorn is approximately 4100 square kilometres. At M.D. of Bighorn, the Bow River flow is partly regulated by hydroelectric reservoirs on the major tributaries, the Cascade and Spray Rivers. The Cascade River project was completed in the year 1942. The storage project on the Spray River was completed in the year 1951. Before these projects there was not any regulation of the Bow River flows except for a small storage dam on the Cascade River (Lake Minnewanka) built in 1912.

At M.D. of Bighorn, the flood events on the Bow River are primarily open-water floods. These usually occur in the month of June caused by a combination of snowmelt and spring rainfall runoff from the Rocky Mountains. Major summer rainstorms may also cause high flows but usually these are not as large as the spring events.

A review of historical flooding in the late 1800's and early 1900's at Canmore is presented in Alberta Environment (1977). These flood events would also have occurred at M.D. of Bighorn but probably did not cause any flooding in developed areas since no records of damage could be ascertained from available archives.

2.2 Recorded Bow River Open-Water Floods

A hydrometric station, Bow River near Kananaskis - 05BE003, was operated by Water Survey of Canada (WSC) just downstream of the study reach during the years 1912 to 1922. No significant inflow is anticipated between the study reach and the station location; thus the discharge at this station would be approximately the discharge at the downstream end of the study reach. This station recorded only one major flood, in 1916, which had a mean daily discharge of 600 m^3/s. It is estimated that the peak instantaneous discharge would have been approximately 645 m^3/s which

is a 40-year return period flood based on Alberta Environmental Protection's flood frequency analysis.

For the years 1923 to 1962 and 1979 to 1995, the Bow River discharge has been recorded at Seebe, WSC Station No. 05BE004. The historical flooding in the study reach can be estimated from the flows at this station after subtracting the inflow from Kananaskis River recorded at WSC Stations 05BF001 and 05BF025.

Table 2-1 presents the Bow River discharges for the ten largest floods recorded at Seebe and Kananaskis and the estimated maximum instantaneous discharge at the downstream end of the Bow River study reach.

Largest Floods on the Bow River Recorded at Seebe/Kananaskis and Estimated Maximum Instantaneous Discharge in Study Reach		
Recorded Maximum Instantaneous Discharge (m^3/s)	**Estimated Maximum Instantaneous Discharge in Study Reach (m^3/s)**	**Date**
645 e (05BE003)	645	June 21, 1916
697 (05BE004)	594	June 15, 1923
705 (05BE004)	594	June 17, 1933
903 (05BE004)	566	June 2, 1932
699 (05BE004)	540	June 3, 1929
583 (05BE004)	487	June 27, 1927
515 (05BE004)	449	June 29, 1928
448 e (05BE003)	448	June 28, 1915
440 e (05BE003)	440	June 18, 1918
429 e (05BE003)	429	July 13, 1920

Table 2-1

Note:"e" denotes that the maximum instantaneous discharge is estimated, based on a power regression between daily mean and instantaneous discharges developed by Alberta Environmental Protection.

2.3 Flooding on Exshaw Creek

Exshaw Creek is an ungauged stream, thus flood flow records are not available. Historic archives from the Glenbow Museum report of frequent flash flooding at Exshaw before construction of the cement plant in 1907. Because of the flooding, containment works were built to control the path of Exshaw Creek. Records of work on the creek or any flood events that occurred have not been maintained by the cement plant staff.

Conversations with residents of Exshaw revealed that the stream has never overflowed its banks in recent history. One resident, who has been living in Exshaw since 1945, said that in 1948 a rainstorm combined with a melting snowpack caused very high flows in the creek. During this event there was extensive erosion of the banks and some buildings adjacent to the creek were damaged when the footings were undermined. As well, there was a tremendous noise from the movement of bed material during the flood event.

2.4 Ice-Related Floods

There does not appear to be any history of flooding as a result of ice cover formation or ice jamming during breakup of the ice cover in the M.D. of Bighorn. Generally ice breakup tends to be uneventful since the cover melts away before any significant runoff occurs from the snow packs in the mountains. As well, the regulation of the Bow River inflows by the Rundle and Cascade Power Plants have changed the natural ice regime. During the winter, the flows are controlled at these plants to minimize flooding in the Town of Canmore. These conditions would also exist in the study area.

In the winter, it is expected that Exshaw Creek would have very low flows and thus it is unlikely to experience ice related flooding.

3 Available Data

3 Available Data

3.1 Hydrology Report

The Surface Water Assessment Branch of Alberta Environmental Protection authored a report entitled "Flood Frequency Analyses Bow River Floodplain Study," dated January 1994. The results of their detailed flood frequency analyses for the Bow River study reach and Exshaw Creek are summarized below.

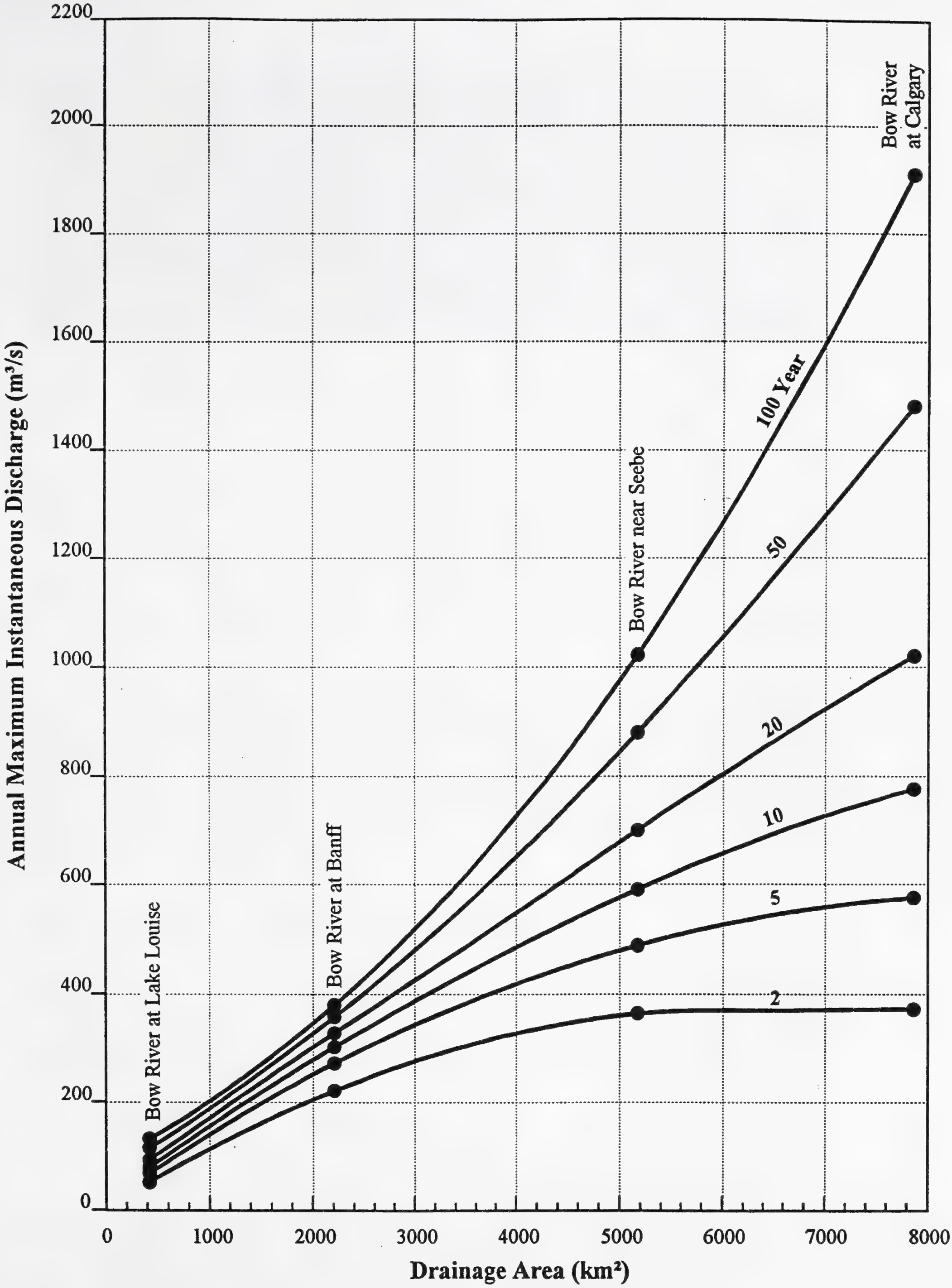
3.1.1 Bow River Flood Frequency Analysis

The analysis for the Bow River was based on flood records from Water Survey of Canada stations on the Bow River. The stations which were used in the analysis are as follows:

05BA001 - Bow River at Lake Louise
05BB001 - Bow River at Banff
05BE004 - Bow River near Seebe
05BH004 - Bow River at Calgary

The study concluded that the influence on peak flows of flow regulation and diversion at the various upstream developments is negligible, especially for higher return period flood events. Thus the annual recorded maximum instantaneous discharges for the above stations were used to estimate the magnitude and frequency of expected future flood flows.

Flood frequency estimates were derived using the Pearson Type III distribution for the Bow River stations and plotted against their respective drainage areas. This plot shown in Figure 3-1, was then used to estimate the flood values for the study reach. The results are given in Table 3-1.



Bow River Flood Frequency Estimates

Figure 3-1

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Note: **This figure is reproduced from Alberta Environmental Protection's report Flood Frequency Analyses Bow River Floodplain Study**

Bow River near Exshaw Flood Frequency Estimates		
Return Period (years)	Annual Maximum Instantaneous Discharge (m^3/s)	
	near Pigeon Mountain Area = 4000 km^2	above Kananaskis River Area = 4160 km^2
100	728	762
50	652	680
20	546	568
10	486	500
5	417	429
2	326	334

Table 3-1

The 100 year flood peak discharge at the upstream end of the Bow River study reach near Pigeon Mountain is estimated to be 728 m^3/s which accounts for the runoff from the upstream drainage basin. The 100 year flood peak discharge at the downstream end of the study reach is estimated to be 762 m^3/s. The increase in discharge accounts for the additional inflows from local drainage such as Exshaw Creek, Heart Creek, Jura Creek and other local inflows.

3.1.2 Exshaw Creek Flood Frequency Analysis

Exshaw Creek is an ungauged stream and the flood flows were estimated using a regional analysis based on recorded natural stream flows in the vicinity of Exshaw. The Water Survey of Canada stations used for this analysis were as follows:

- 05BF018 - Twin Creek near Seebe
- 05BF017 - Middle Fork Creek near Seebe
- 05BJ009 - Little Elbow River above Nihahi Creek
- 05BG002 - Ghost River near Black Rock Mountain
- 05BJ006 - Elbow River above Elbow Falls
- 05BD005 - Cascade River above Lake Minnewanka

Using the data from these stations, an equation to estimate the mean annual maximum instantaneous flood discharge in the region was derived:

$$Q_{MAF} = 0.180684\,(A)^{0.95435}$$

where: Q_{MAF} is the mean annual flood (m^3/s)
A is the drainage area (km^2)

The ratio of various return period flood estimates compared to the mean annual flood discharge was also derived from the data. Table 3-2 gives the ratios of peak discharge to mean discharge for the region and the corresponding discharge values for Exshaw Creek.

Regional Ratio of Peak Discharge to Mean Discharge and Exshaw Creek Flood Estimates							
Return Period (years)	**100**	**50**	**25**	**20**	**10**	**5**	**2**
Peak/Mean Ratio	2.87	2.53	2.18	2.07	1.72	1.36	0.86
Flood Estimate (m^3/s)	14.3	12.6	10.9	10.3	8.57	6.77	4.28

Table 3-2

3.2 Base Mapping and River Cross Section Surveys

Alberta Environmental Protection provided orthophoto maps at 1:5000 scale with one metre contours of the Bow River valley. A cross-section database for each of the Bow River and Exshaw Creek study reaches was supplied by Alberta Environmental Protection in HEC-2 format. The Bow River database had data for 21 cross-sections that were used to model the Bow River and its floodplain for the natural conditions. The Exshaw Creek database had data for 27 cross-sections that were used to model Exshaw Creek in its existing condition. An overlay with the cross-section locations was included with the orthomaps. Distances between cross-sections were measured using these maps and overlays.

The dykes at Lac des Arcs did not exist at the time the base maps and cross-sections were prepared. Thus, a report entitled Lac des Arcs and Exshaw Beach Dust Control Program, Preliminary Design Report was used to provide the data for the recently built dykes at Lac des Arcs. This report was prepared for M.D. of Bighorn No. 8 by Scott and Associates Engineering Limited in association with Hydroconsult EN3 Services Ltd., Thurber Engineering Limited and Environmental Management Associates.

3.3 High Water Levels

Alberta Environmental Protection measured water surface profiles of the Bow River through Canmore on May 30, 1986 and June 2, 1990. The most downstream measurement of the water surface profiles is the only point that falls within the current study reach. The most downstream measurement was taken at site Bow-18 at 7:10 pm on May 30, 1986 and 3:40 pm on June 2, 1990. Bow-18 is located at Gap Lake, legal location NE-18-24-9W5M. The water level measured on May 30, 1986 was 1292.05 m and on June 2, 1990 was 1292.20 m.

These measured water levels are referred to as high water marks (HWM's), however they are not, since they were not measured at the time of the peak flow. For example, in the May 30, 1986 flood the peak flow actually occurred on June 2, 1986 according to Water Survey of Canada data at station 05BB001 - Bow River at Banff and station 05BE004 - Bow River Near Seebe.

No estimated high water levels were available for Exshaw Creek.

3.4 Rating Curve

No rating curves were available for the study reach, since gauging station data was not available within the study reach. In the Canmore Flood Risk Mapping Study done by
W-E-R AGRA LTD. (1993) an analysis was done for the gauging station Bow River at Canmore, WSC Station No. 05BE008. The analysis revealed that the Manning's n value approached a constant value for discharges over 150 m^3/s. The two year flood discharge at this station is 318 m^3/s. Thus the Manning's n was not varied for discharge in the Canmore study.

In this study the calibration flow downstream of Exshaw is 302 m^3/s, which is almost the 2 year flood of 334 m^3/s for this reach of the Bow River. Therefore, the calibrated Manning's n values discussed in Section 5 of this report were not adjusted for discharge.

3.5 Aerial Photography

Aerial photographs of the study reach were taken by Foto Flight Surveys Limited on June 5, 1986. These photographs were used to estimate the extent of flooding during the 1986 flood event for calibration of the Bow River HEC-2 model.

4 River/Valley Features

4 River/Valley Features

4.1 Bow River Features

The study reach of the Bow River is located in a wide glacial mountain valley. The valley is approximately 1000 to 1700 metres wide and is flanked by alluvial fans and terraces. The valley contains the Bow River floodplain which varies from 100 to 1500 metres in width. The floodplain is composed of glacial melt water channel deposits and recent alluvium. The floodplain, terraces and fans are treed primarily with coniferous vegetation in the upstream region of the study reach with increasing amounts of deciduous trees and wild grasses in the downstream direction.

4.1.1 Bow River Channel Characteristics

The Bow River channel has an irregular meandering pattern and is confined by valley walls or by high terraces in many locations. There are several islands and diagonal, side, mid-channel and point bars. The river profile upstream of Exshaw is relatively flat with an average slope of 0.0002. Downstream of Exshaw the river profile is fairly steep with an average slope of 0.0019.

The channel bed is predominantly gravel but in the Lac des Arcs area the bed is silty-sand with many sand bars in the main channel. Upstream of Lac des Arcs, fine deposits are intermixed with the gravel bed. Presumably, during large floods, the fine sediments in the upstream area are carried in suspension and the gravel forms the predominant bed feature. In the reach downstream of Exshaw Creek, the bed material is made up of large gravel sizes due to the influx of bed material from Exshaw Creek and Heart Creek.

The channel banks consist mainly of alluvial sand and gravel with some areas made up of glacial deposits. In a few areas unstable banks occur on the outside of river bends. There are no known bedrock exposures within the river channel in the study reach.

4.1.2 Bow River Floodplain Characteristics

The active floodplain along the river is clearly identifiable. The vegetation on the floodplain consists of bushes and trees of medium to high density. Many channels or channel remnants exist on the floodplain. Some of these channels convey water during floods. The active floodplain is mostly undeveloped land except for recent developments in the Exshaw Industrial Park.

4.1.3 Man-Made Features

The area along the reach of Bow River under study is relatively undeveloped. Except for the recently built dykes along Lac des Arcs and the CPR railway no other developments affect the Bow River. The CPR railway parallels the river along the left edge of the floodplain. In some locations the railway ballast and side slope armoring encroach on the river channel to a limited extent. The recently built dykes separate Lac des Arcs from the main river channel and do not encroach on the main channel. The dykes were built to control Lac des Arcs water levels during the winter to reduce the dust problem caused by blowing lake bed sediments when water levels drop in Lac des Arcs.

4.2 Exshaw Creek Features

Exshaw Creek is a steep mountain creek that flows through an incised valley and then onto an alluvial fan in the Bow River valley. The study reach covers the alluvial fan area where the creek traverses through the Town of Exshaw. Since construction of the cement plant in 1907, the creek has been restricted by training works to the east of the cement plant. The cement plant staff have not maintained records of berm maintenance or upgrading. A large berm presently exists along the west side of the creek in the reach next to the cement plant.

Exshaw Creek over bank areas are developed on both sides. However, the areas directly adjacent to the creek are generally open land with a light cover of prairie grass. The creek has a fairly consistent slope of 4.7 percent through most of the study reach. Over the last 150 m the slope flattens to 2.3 percent before the creek empties into the Bow River. Bed material in the creek is mainly gravel and cobbles with a few boulders. The banks are composed of alluvial deposits of sand, gravel, and cobbles.

There are five bridge crossings on Exshaw Creek. Three of the bridges are near the downstream end of the creek. These are the Highway 1A bridge, CPR bridge, and an access road to the Exshaw Industrial Park. The other two bridges are both pedestrian crossings, one is located about midway through the study reach, the other is near the upstream end. At some of the bridges, erosion protection is provided on the upstream and downstream banks.

5 Calculation of Flood Levels

5 Calculation of Flood Levels

5.1 HEC-2 Program

Water surface profiles were calculated using the HEC-2 steady state computer model (Version 4.6, May 1991). An extended version of this program which can use the large cross-section data sets generated by present survey methods was obtained from AGRA Earth & Environmental Ltd.. The HEC-2 program was developed by the Hydrologic Engineering Centre of the US Army Corps of Engineers. It was designed for calculating water surface profiles for steady and gradually varied flow in natural or man-made channels.

The HEC-2 program can;

- calculate subcritical and supercritical flow profiles,
- model structures such as bridges, culverts and weirs, and
- assess the effects of channel encroachments, channel improvements, and levees.

Other program features include a formatted data editor, data error checking, various output options, and profile and cross-section plotting features.

The model calculates the water surface profiles using the standard step method to solve the one-dimensional energy equation between successive cross-sections. This method of calculation does not allow the simultaneous calculation of subcritical and supercritical flow regimes. Thus if the flow regime changes in a channel, separate runs are required to compute the water levels. The results from the two runs are then superimposed to determine the appropriate water surface profile using a conjugate depth analysis at each cross-section.

5.2 Geometric Database

5.2.1 Bow River Data

A cross-section database for the Bow River was supplied by Alberta Environmental Protection in HEC-2 format. The database contains data for 21 cross-sections. These cross-sections were used to model the Bow River and its floodplain for both the natural and existing conditions. No river crossings exist in the Bow River study reach.

Alberta Environmental Protection provided orthophoto maps of the Bow River valley with locations of the river cross-sections. Details of the dykes at Lac des Arcs were obtained from a report entitled Lac des Arcs and Exshaw Beach Dust Control Program, Preliminary Design Report.

5.2.2 Exshaw Creek Data

Alberta Environmental Protection provided data for 27 cross-sections on Exshaw Creek in HEC-2 format. Additional survey information was also provided for four of the five bridges on Exshaw Creek. Information on the recently constructed fifth bridge was obtained from Alberta Transportation. The bridge data was incorporated into the cross-section data to complete the data set for the HEC-2 model of Exshaw Creek. A second data set was created for Exshaw Creek with the cross-sections in reverse order so that subcritical and supercritical profiles could be calculated.

5.3 Hydraulic Parameters

5.3.1 Expansion Contraction Coefficients

Energy losses caused by changes in effective flow area are calculated in HEC-2 by multiplying the change in velocity head between cross-sections by a coefficient. These expansion and contraction coefficients vary with the abruptness of the change in area. Natural channels typically have gradual changes in area with coefficients of 0.1 and 0.3 for contraction and expansion respectively. Channel obstructions can cause rapid contraction and expansion of the flow with coefficients as high as 0.6 and 0.8 respectively.

The contraction and expansions in the Bow River study reach were considered to be gradual thus 0.1 was used for the contraction coefficient and 0.3 for the expansion coefficient. The same values were used on Exshaw Creek. The bridge abutments on Exshaw Creek do not create a rapid contraction or expansion so the coefficients were not changed at the bridge sections.

5.3.2 Manning's Roughness

The Manning's equation is used by the HEC-2 program to compute energy loss from friction between cross-sections. The value of the calibration parameter, Manning's n, depends on the characteristics of the channel such as vegetation, channel irregularity, stage, discharge and bed roughness. The water surface profile of a river can be very sensitive to the Manning's n value. HEC-2 requires Manning's n, river discharge, and the geometry of each cross-section to calculate the friction loss between sections.

In this study, the Manning's n values for the Bow River channel were calibrated using available data from the 1986 flood. Data was not available for calibration of the floodplain Manning's n. Thus, the Bow River floodplain Manning's n value was estimated from field observations and a procedure described in Arcement and Schneider (1989). This procedure accounts for various factors such as soil surface roughness, surface irregularities, obstructions, and vegetation. Based on these factors, the densely vegetated and highly irregular flood plain for the Bow River is estimated to have a Manning's n value of 0.25.

Since data was not available for calibration of the Exshaw Creek HEC-2 model, the selection of Manning's n values for the channel and floodplain were based upon visual inspection and accepted reference literature. Chow (1959) suggests a Manning's n of 0.04 for a mountain stream with steep banks, no vegetation, and a bed of gravel, cobbles, and a few boulders. The floodplain Manning's n value was selected to be 0.03. The lower floodplain value reflects the sparsely vegetated, graded land adjacent to Exshaw Creek.

5.4 Model Calibration

5.4.1 Methodology

The main parameter used for calibration of the Bow River model was the channel Manning's n. The methodology used, for adjustment of the Manning's n, was to run the HEC-2 program and compare the output data to the available records for the 1986 flood. Both the high water mark (HWM) data collected by the River Engineering Branch of Alberta Environmental Protection on May 30, 1986 and the aerial photographs taken on June 5, 1986 were used for calibration. The starting water level was estimated in HEC-2 using the normal depth and an energy slope of 0.00081. The energy slope was calculated from the calibration run results.

Only one HWM was recorded during the 1986 flood which was located about 645 m upstream of Cross-section 20. For the rest of the study reach, the river flow widths calculated at each cross-section by the HEC-2 model were compared to those measured from the inundated areas in the aerial photographs. The average daily discharges along the Bow River were estimated to be 298 and 302 m^3/s upstream and downstream of Exshaw Creek, respectively. These discharges are just under the peak flows for a 2-year return period flood event.

Modifications to the river cross-sections were also required in regions where floodplain areas do not contribute effective flow-area. These areas can be blocked

out so that they do not contribute to the flow-area using HEC-2's encroachment wall option.

Verification of the calibrated Bow River model was achieved through comparison to field data collected by the River Engineering Branch of Alberta Environment on June 2, 1990. The estimated daily flows for the June 1990 flood event were 310 and 315 m^3/s upstream and downstream of Exshaw Creek, respectively.

5.4.2 Results

5.4.2.1 Bow River

The calibrated main channel Manning's n values are presented in Table 5-1. The Manning's n values of 0.027 for Cross-sections 1 to 9 and 0.025 for Cross-sections 14 to 21 are typical for a gravel bed channel with a clean uniform section. The larger Manning's n value of 0.033 for Cross-sections 10 to 13 reflect the larger bed material size and the form roughness in this steeper reach of river. Previous reports were reviewed to verify that the values chosen for Manning's n were reasonable.

Some modifications were required to the Bow River cross-section database to provide a better representation of the Bow River. The modifications were as follows:

At Cross-sections 2, 3, 6 to 10, and 16 to 21 encroachment walls were applied to one or both sides of the floodplain to cut off ineffective flow areas.

A cross-section was interpolated between Cross-sections 4 and 5. This was required because of the large change in conveyance between the two cross-sections.

Calibrated Main Channel Manning's Roughness Coefficients Bow River Reach	
Cross-Sections	**Manning's n**
1 - 9	.027
10 - 13	.033
14 - 21	.025

Table 5-1

A cross-section was interpolated between Cross-sections 6 and 7. This was required because of the large change in conveyance between the two cross-sections.

In the Lac des Arcs area, the cross-sectional area of the lake was reduced by raising the lake bed. For the calibration runs the lake bed was raised to 1291.3 m at Cross-section 14, 1291.45 m at Cross-section 15, and 1291.5 m at Cross-section 16. This was done because the natural high ridge along the right side of the main channel limits the flow through the lake. For the existing conditions the bed level of the lake was raised to the top of dyke elevation of 1292.0 m at Cross-sections 14, 15, and 16.

A comparison between the river flow widths computed by the HEC-2 model and those measured from the inundated areas in the aerial photographs are presented in Table 5-2. Aerial photographs of the downstream reach, Cross-sections 1 to 3, were not available. The difference between the computed and measured widths were reasonable except in areas where flooding in the treed floodplain were difficult to delineate from the aerial photographs. The computed water surface elevations for the 1986 flood are presented in Table 5-3. The water surface profile is illustrated in Figure 5-1 along with the measured HWM, channel thalwegs and critical water levels. It can be seen that the river reach from Cross-sections 4 to 11 is quite steep and the flow approaches critical depth.

The HWM measured on May 30, 1986 was 1292.05 m at a location approximately 645 m upstream of Cross-section 20. The computed water elevation at this location, was estimated to be 1292.10 m. The difference between the computed and measured HWM can be accounted for by the variation of instantaneous discharge throughout the day, the accuracy of the field data and model computations.

The HWM measured on June 2, 1990 was 1292.20 m at the same location as the HWM of May 30, 1986. The water level computed at this location by the HEC-2 model was 1292.16 m. The small difference in elevation is within the anticipated accuracy of the model. The computed water levels for the 1990 flood are presented in Table 5-3 and illustrated on Figure 5-2.

Table 5-2
Comparison of Measured River Flow Width on June 5, 1986 and Calculated River Flow Width Based on the Calibrated Manning's n

Cross Section Number	Cumulative Chainage (m)	Measured Channel Topwidth (m)	Calculated Channel Topwidth (m)	Difference in Channel Topwidth (m)	Notes
1	0	NA	291.8	NA	
2	320	NA	282.39	NA	
3	1080	NA	254.28	NA	
4	1490	300	307.54	+7.54	
4.1	1800	100	229.27	+129.27	Flooding in trees
5	2230	150	199.56	+49.56	Flooding in trees
6	2565	140	154.52	+14.52	
6.1	2735	150	192.77	+42.77	Flooding in trees
7	3015	160	231.91	+71.91	Flooding in trees
8	3380	130	152.8	+22.80	Flooding in trees
9	3735	120	130.21	+10.21	
10	4175	90	98.37	+8.37	
11	4380	50	60.52	+10.52	
12	4690	70	66.59	-3.41	
13	5090	400	396.62	-3.38	
14	5890	1025	1075.25	+50.25	
15	6745	710	781.57	+71.57	
16	7925	1100	1204.36	+104.36	
17	9065	160	161.03	+1.03	
18	10545	130	133.9	+3.90	
19	11725	100	127.92	+27.92	
20	12480	115	149.93	+34.93	
21	14930	100	93.66	-6.34	

NA - Not available

Table 5-3
Computed Water Surface Profiles, Bow River Reach

Cross-Section No.	Water Surface Elevation (m)	
	1986 Flood	1990 Flood
1	1282.58	1282.61
2	1282.85	1282.88
3	1283.46	1283.50
4	1283.91	1283.95
4.1	1284.13	1284.16
5	1285.26	1285.29
6	1285.69	1285.72
6.1	1285.97	1286.01
7	1286.30	1286.33
8	1287.05	1287.08
9	1288.01	1288.05
10	1289.47	1289.51
11	1290.22	1290.26
12	1291.21	1291.27
13	1291.52	1291.58
14	1291.53	1291.60
15	1291.62	1291.68
16	1291.75	1291.80
17	1291.81	1291.86
18	1291.88	1291.93
19	1291.95	1292.01
20	1292.01	1292.07
21	1292.36	1292.42

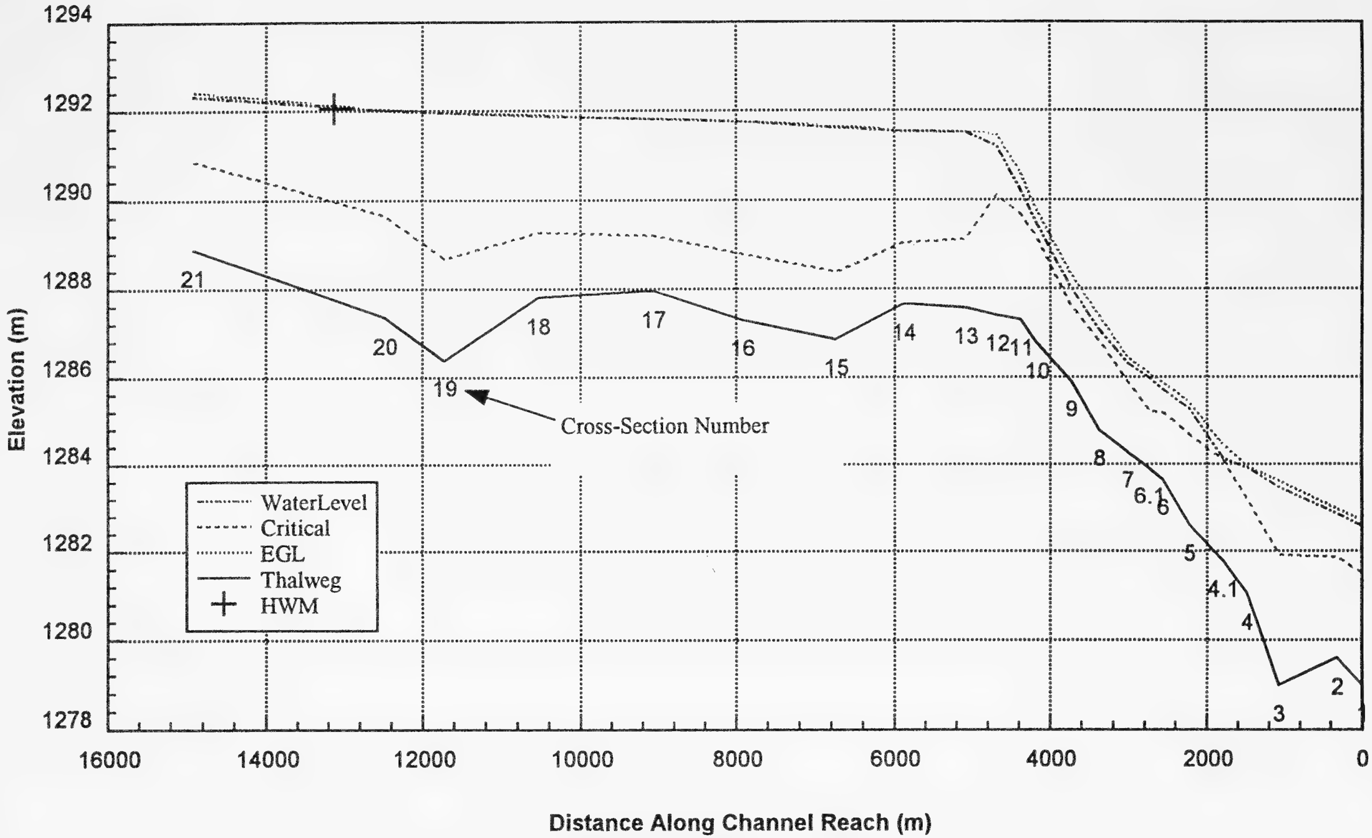

Figure 5-1

Computed Water Surface Profile for 1986 Flood
Bow River Reach

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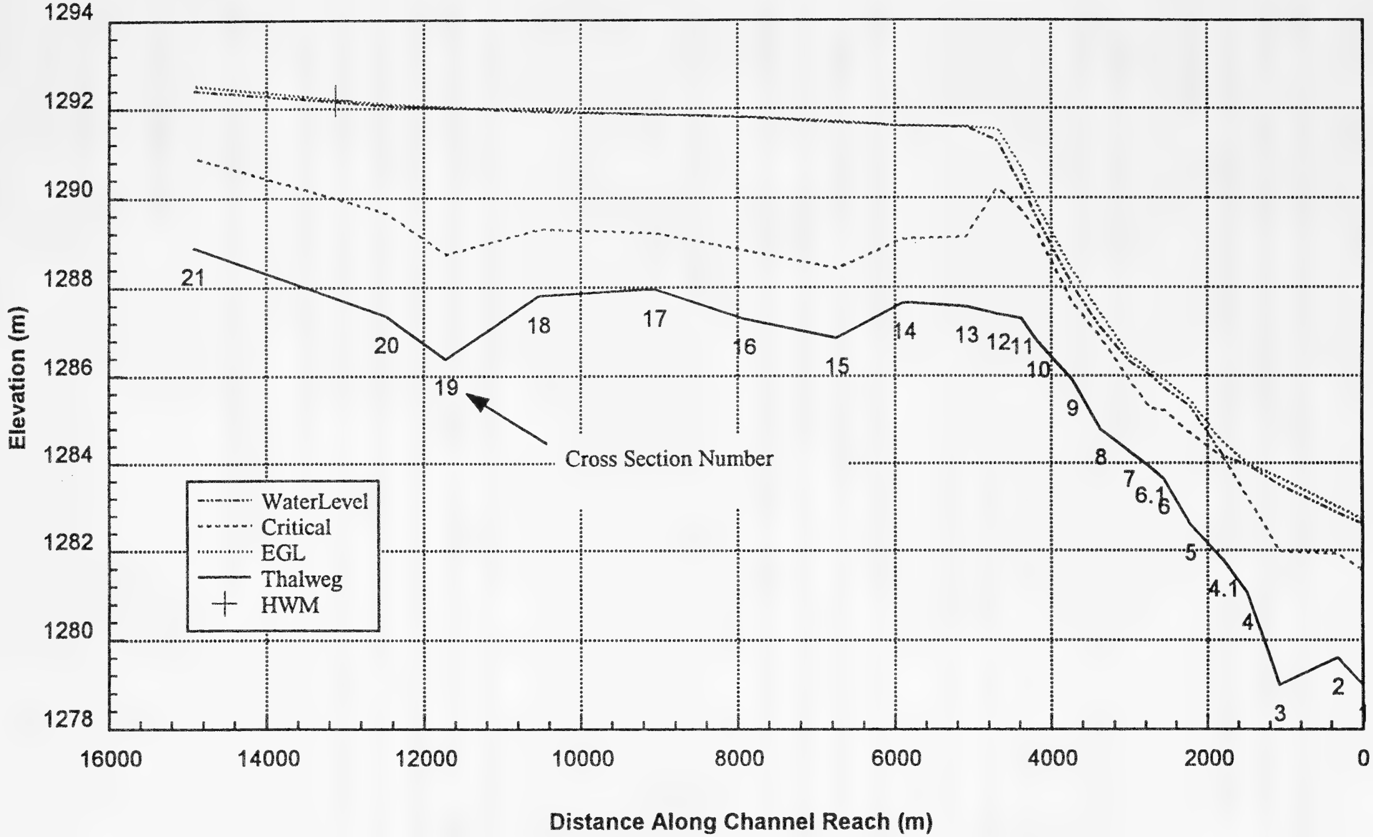

Figure 5-2

Computed Water Surface Profile for 1990 Flood
Bow River Reach

ACRES

5.4.2.2 Exshaw Creek

The Exshaw Creek cross-section database could not be used in its original form. Several of the cross-sections indicated that the outer limits of the floodplain were far below the main channel invert and this caused an execution error in the HEC-2 program.

The data for these problematic cross-sections were adjusted to omit these low-lying floodplain areas so that preliminary runs could be executed with the HEC-2 program. The preliminary runs indicated that the flood waters would remain in the main channel so the revised database was used for the remaining HEC-2 analysis. If the preliminary runs had indicated that the creek would overflow its banks further modifications to the database would of been required to correctly model the floodplain areas.

HEC-2's normal bridge method was used to model all the bridges. This method treats a bridge cross-section in the same manner as a natural river cross-section. Bridge decks were included in the section data to account for flow pressurizing and over-topping if it were to occur at the small bridge openings on Exshaw Creek.

Using the selected channel Manning's n of 0.040 and a floodplain Manning's n of 0.030, a water surface profile was calculated for the 100 year flood discharge of 14.3 m^3/s. The model results showed that the flow was conveyed in the main channel and that the channel velocities were sufficient to cause bed load transport. Critical depth was used as the starting elevation at the upstream end of the study reach.

The flow was supercritical throughout the study reach, keeping just below critical depth except at the bridge locations where the flow went through critical. The critical flow at the bridges prompted a HEC-2 run to be made in the opposite direction to check if there would be subcritical flow upstream of the bridges. This run showed the flow going through critical at all of the cross-sections, indicating that the flow would remain supercritical throughout the study reach.

5.5 Computer Water Surface Profiles

5.5.1 Bow River

The simulation of the 1986 flood was undertaken with the conditions that existed at that time. In 1993, three dykes were constructed around Lac Des Arcs to control the water level in the lake. These dykes were constructed at the inlet to the lake and around the downstream end of the lake. The top elevations of all three dykes are 1292.0 m. For simulation of the effects of these dykes on the river hydraulics, the

lake bottom was raised to Elevation 1292.0 m in Cross-sections 14, 15 and 16. The revised HEC-2 model simulating the existing conditions was then used to calculate the 2, 5, 10, 20, 50 and 100 year floods.

The starting water levels for the flood profiles were calculated in HEC-2 using the normal depth and energy slope of 0.00081. This energy slope was derived from the 1986 flood calibration run.

For each flood simulation, the encroachment walls were adjusted, as appropriate, to exclude ineffective flow areas.

The computed water surface elevations for each flood event are presented in Table 5-4. The water surface profiles for each flood event are illustrated in Figure 5-3. The study reach was divided into three separate reaches based on the bed slope of the channel. Average reach hydraulic parameters are shown in Table 5-5.

The 10 year flood discharge is about 65% of the 100 year flood and corresponding water levels are lower by 0.4 to 1.0 m.

5.5.2 Exshaw Creek

Supercritical water surface profiles were computed for the 2, 5, 10, 20, 50 and 100 year flood events on Exshaw Creek. All six flood events were contained within the main channel. Flow restrictions at the bridges did not occur, since the water levels were below the bottom chords of all the bridges.

A channel Manning's n of 0.04 was assumed for the full range of flood events. The initial starting level for each profile was assumed to be critical depth at the upstream end of the study reach.

The water surface profile elevations are presented in Table 5-6. Average hydraulic parameters for the entire Exshaw Creek reach are presented in Table 5-7. The water surface profile for the 100 year flood is illustrated in Figure 5-4 which shows the flow is slightly below critical depth over the whole study reach. However, the flow does go through critical at the bridges which suggests the occurrence of weak hydraulic jumps upstream of the bridges. The Froude Numbers of the inflow and outflow of these jumps are close to 1.0 so the jump would not be noticeable.

Based on the profile in Figure 5-4, it is likely that the flow in Exshaw Creek will form a series of pools and riffles as the bed load sediments migrate along in waves and

Table 5-4
Computed Water Surface Profiles
Bow River Reach

Cross-Section No.	Water Surface Elevation (m)					
	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
1	1282.63	1282.83	1282.97	1283.08	1283.26	1283.38
2	1282.90	1283.09	1283.22	1283.33	1283.49	1283.60
3	1283.54	1283.80	1283.97	1284.12	1284.36	1284.52
4	1283.99	1284.27	1284.46	1284.62	1284.87	1285.04
4.1	1284.19	1284.44	1284.61	1284.75	1284.99	1285.15
5	1285.31	1285.51	1285.63	1285.73	1285.91	1286.03
6	1285.74	1285.97	1286.12	1286.24	1286.43	1286.56
6.1	1286.04	1286.28	1286.44	1286.57	1286.78	1286.93
7	1286.37	1286.60	1286.76	1286.90	1287.11	1287.26
8	1287.05	1287.23	1287.36	1287.46	1287.64	1287.76
9	1288.01	1288.21	1288.33	1288.42	1288.56	1288.64
10	1289.58	1289.84	1290.02	1290.17	1290.42	1290.59
11	1290.28	1290.51	1290.64	1290.76	1290.90	1290.98
12	1291.36	1291.74	1292.01	1292.24	1292.62	1292.90
13	1291.69	1292.13	1292.43	1292.70	1293.14	1293.45
14	1291.70	1292.14	1292.44	1292.72	1293.15	1293.47
15	1291.82	1292.28	1292.56	1292.80	1293.20	1293.51
16	1291.98	1292.43	1292.67	1292.89	1293.27	1293.56
17	1292.05	1292.48	1292.71	1292.93	1293.30	1293.58
18	1292.12	1292.55	1292.79	1293.01	1293.38	1293.66
19	1292.19	1292.64	1292.88	1293.11	1293.49	1293.78
20	1292.24	1292.69	1292.94	1293.17	1293.55	1293.84
21	1292.55	1292.97	1293.23	1293.46	1293.83	1294.11

Table 5-5
Average Hydraulic Parameters for Various Flood Simulations, Bow River Reach

Cross Sectional Reach		Hydraulic Parameters	Flood Frequency					
From	To		2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
1	9	Average Depth of Flow (m)	2.8	3.0	3.1	3.2	3.4	3.6
		Average Channel Velocity (m/s)	1.9	2.1	2.2	2.3	2.4	2.5
		Energy Slope	0.0015	0.0015	0.0016	0.0016	0.0016	0.0016
10	12	Depth of Flow (m)	3.2	3.5	3.7	3.9	4.2	4.3
		Average Channel Velocity (m/s)	2.6	2.9	3.0	3.2	3.5	3.7
		Energy Slope	0.0035	0.0037	0.0038	0.0040	0.0042	0.0044
13	21	Depth of Flow (m)	4.5	4.9	5.2	5.4	5.8	6.1
		Average Channel Velocity (m/s)	0.8	0.8	0.8	0.8	0.8	0.8
		Energy Slope	0.000091	0.000093	0.000088	0.000087	0.000079	0.000077

Table 5-6
Computed Water Surface Profiles, Exshaw Creek

Cross-Section No.	Water Surface Elevation (m)					
	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
1	1291.23	1291.32	1291.39	1291.43	1291.48	1291.51
1.1	1292.39	1292.51	1292.59	1292.66	1292.75	1292.80
1.2	1292.39	1292.51	1292.59	1292.66	1292.69	1292.72
2	1292.36	1292.46	1292.53	1292.59	1292.66	1292.71
3	1293.61	1293.66	1293.69	1293.71	1293.74	1293.76
3.1	1294.03	1294.11	1294.16	1294.21	1294.26	1294.29
3.2	1294.03	1294.11	1294.16	1294.21	1294.26	1294.29
4	1294.03	1294.11	1294.16	1294.20	1294.26	1294.29
5	1294.87	1294.95	1294.99	1295.03	1295.10	1295.14
5.1	1295.50	1295.64	1295.71	1295.78	1295.85	1295.91
5.2	1295.50	1295.64	1295.71	1295.78	1295.85	1295.91
6	1295.50	1295.64	1295.71	1295.78	1295.85	1295.92
7	1297.16	1297.23	1297.28	1297.33	1297.36	1297.39
8	1298.94	1299.04	1299.12	1299.17	1299.25	1299.29
9	1301.21	1301.31	1301.37	1301.42	1301.47	1301.51
10	1303.23	1303.31	1303.39	1303.44	1303.53	1303.58
11	1304.26	1304.39	1304.46	1304.54	1304.62	1304.69
11.1	1304.51	1304.66	1304.75	1304.83	1304.91	1305.00
11.2	1304.51	1304.66	1304.75	1304.83	1304.91	1305.00
12	1304.45	1304.58	1304.65	1304.71	1304.78	1304.82
13	1306.85	1306.94	1306.99	1307.04	1307.10	1307.14
14	1308.97	1309.06	1309.11	1309.14	1309.20	1309.25
15	1311.14	1311.20	1311.27	1311.32	1311.40	1311.44
16	1314.02	1314.19	1314.29	1314.44	1314.53	1314.57
17	1316.50	1316.60	1316.68	1316.73	1316.81	1316.85
18	1319.09	1319.20	1319.25	1319.28	1319.35	1319.39
19	1321.30	1321.39	1321.45	1321.50	1321.57	1321.61
20	1323.94	1324.09	1324.19	1324.26	1324.34	1324.40

Cross-Section No.	Water Surface Elevation (m)					
	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
21	1325.65	1325.79	1325.87	1325.95	1326.04	1326.10
22	1326.37	1326.51	1326.60	1326.68	1326.78	1326.85
23	1326.34	1326.46	1326.52	1326.59	1326.66	1326.71
24	1328.07	1328.18	1328.23	1328.28	1328.34	1328.38
25	1330.37	1330.49	1330.54	1330.60	1330.67	1330.73
26	1333.04	1333.14	1333.21	1333.26	1333.33	1333.39
27	1335.42	1335.55	1335.63	1335.70	1335.78	1335.84

Table 5-7
Average Hydraulic Parameters for Various Flood Simulations, Exshaw Creek

Cross Sectional Reach		Hydraulic Parameters	Flood Frequency					
From	To		2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
1	27	Average Depth of Flow (m)	0.5	0.6	0.7	0.7	0.8	0.9
		Average Channel Velocity (m/s)	2.3	2.6	2.7	2.8	3.0	3.0
		Energy Slope	0.044	0.045	0.045	0.045	0.046	0.045

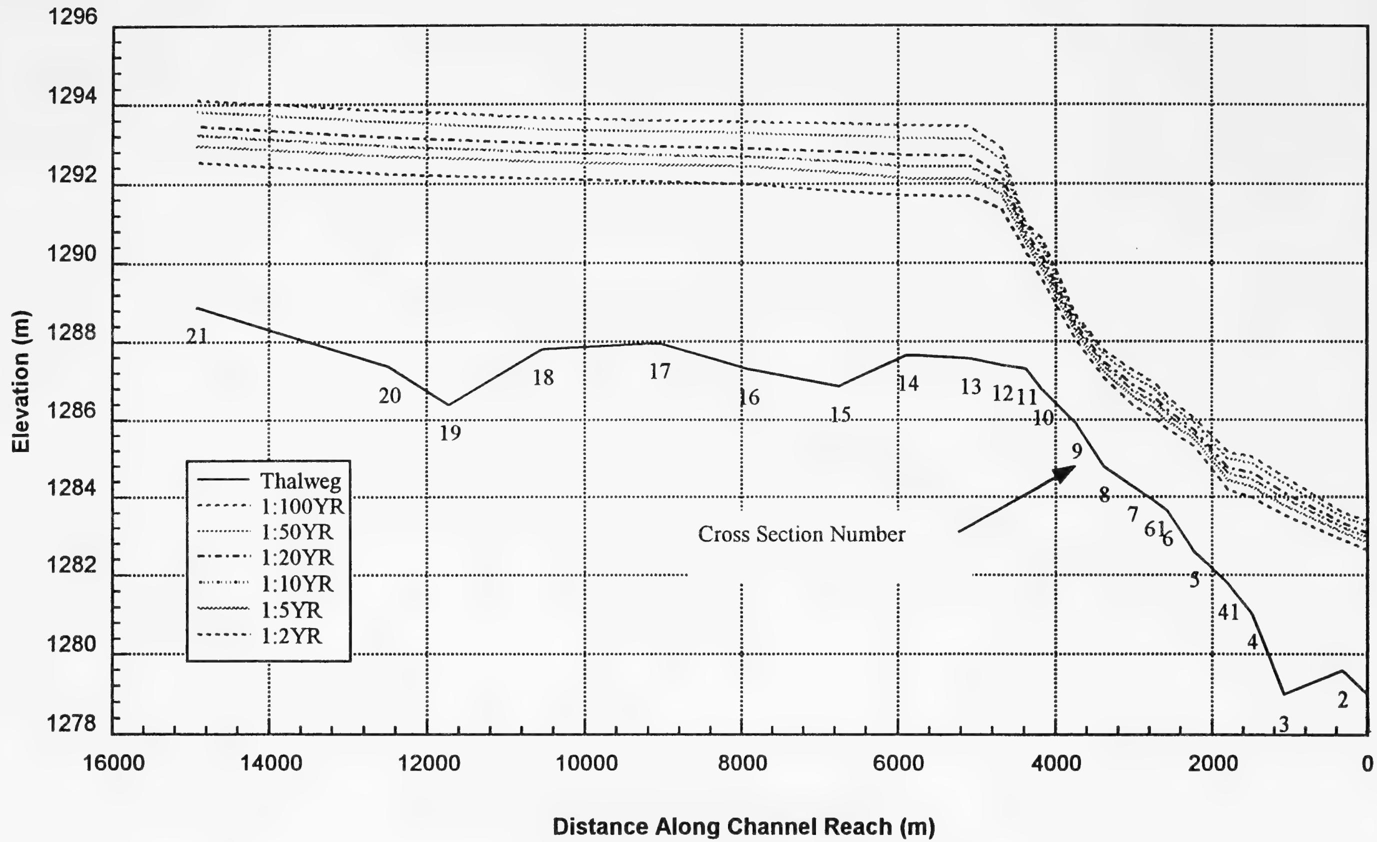

Figure 5-3

Computed Water Surface Profiles for Different Return Period Floods
Bow River Reach

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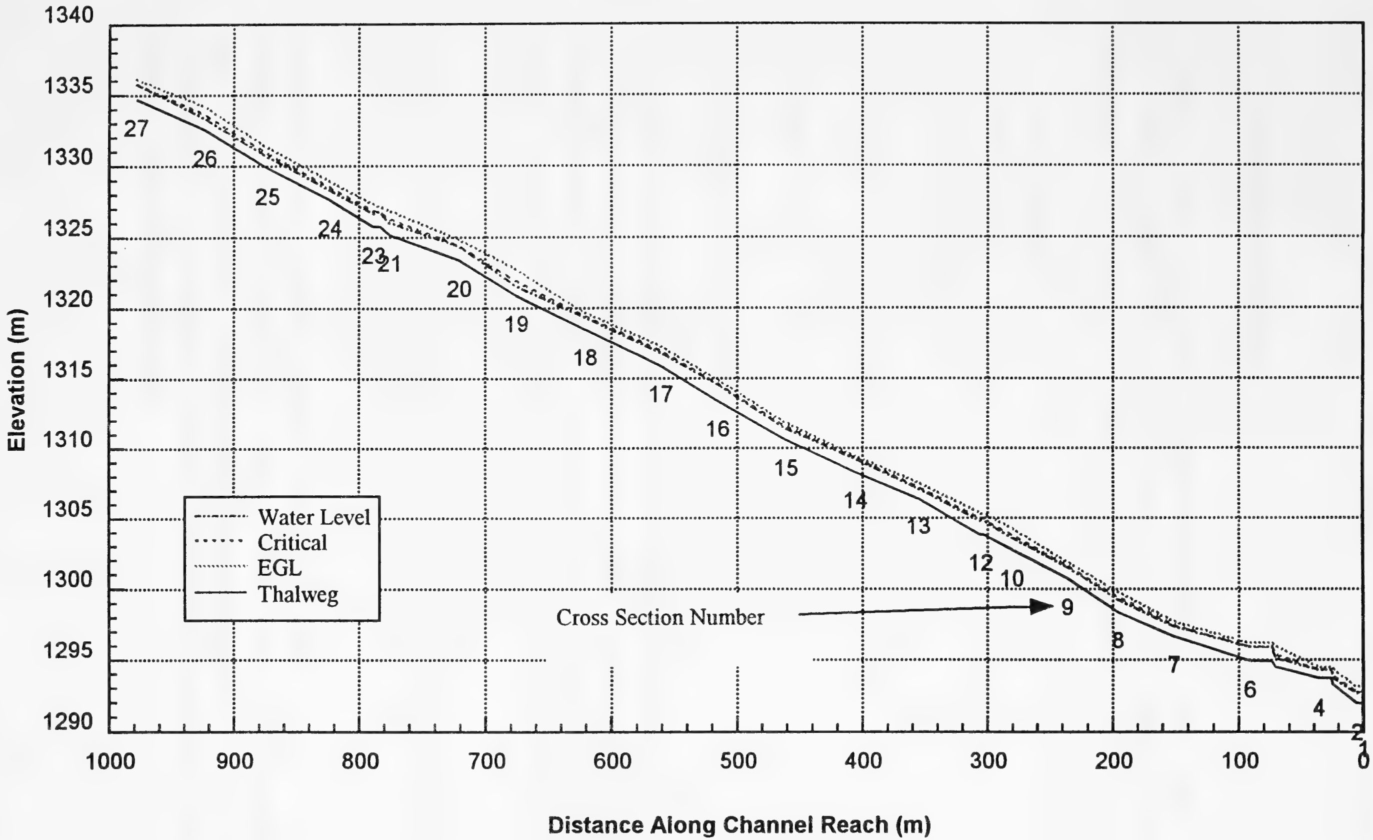

Figure 5-4

Computed Water Surface Profile for 100 Year Flood
Exshaw Creek

ACRES

gravel bars on the channel bottom. HEC-2 cannot model this type of profile as it is a fixed-bed model.

5.6 Model Sensitivity

A sensitivity analysis was performed to determine the potential error in the computed water surface elevations for the 100 year flood event. The analysis involved testing the sensitivity of the computed water levels to the following:

- initial starting level,
- discharge,
- floodplain Manning's n, and
- channel Manning's n.

The results of this analysis is discussed below.

5.6.1 Bow River

5.6.1.1 Initial Starting Conditions

The starting water surface elevations at the downstream end of the Bow River HEC-2 model were calculated by the slope area method. The user supplies the program with the discharge and the slope of the energy grade line at the downstream end. The program then uses Manning's equation to compute the water surface elevation which corresponds to the given slope and discharge.

To test the sensitivity of the computed water levels to the initial starting conditions the initial slope of the energy grade line was increased and decreased by 30 percent and the results are presented on Table 5-8.

Increasing the energy slope by 30% lowers the starting water level by 0.14 m, while decreasing it raises the initial water level by 0.20 m. Variance of the initial energy slope by ±30% effects the 100 year flood water surface profile up to Cross-section 3. Upstream of Cross-section 3 the initial starting conditions had no effect on the computed water surface elevations.

Table 5-8
Sensitivity of Computed Water Levels to Variations in the Initial Energy Slope Bow River Reach

Initial Energy Slope	Variation from the Base Energy Slope (%)	Starting Water Level (m)	Variation from the Base Starting Water Level (m)	Reference Cross-Section (km)
0.0010562	+30	1283.24	-0.14	3
0.0008125	0	1283.38	0	-
0.0005688	-30	1283.58	+0.20	3

Notes:

1) Based on 100 year flood profile

2) The reference cross section is the cross section at which the calculated water levels are within +-0.05 metres of the base simulation.

5.6.1.2 Main Channel Roughness

The channel Manning's n was varied by ±10% to determine the effect on the calculated water surface profiles and the results are presented in Table 5-9. It can be seen that increasing the Manning's n by 10% increases the calculated mean water levels by 0.1 m; decreasing the Manning's n by 10% decreases the water levels by 0.12 m.

5.6.1.3 Floodplain Roughness

The floodplain roughness was varied by ±30% to determine the effect on calculated water surface profiles. The results showed changes of water level of less than 0.05 m. Thus, changes in the estimated floodplain roughness has very little effect on the computed water levels.

5.6.1.4 Discharge

The discharge for the 100 year flood simulation was varied by ±15% to determine the effect on the calculated water surface profiles. Figure 5-5 illustrates the effect of this variation. The water levels at the upstream end of the study reach were increased or decreased by about 0.4 m and the downstream water levels were changed by about 0.2 m. The variation of the flood magnitude by ±15% produced a more significant effect on the water levels than the variations in roughness or starting conditions.

5.6.1.5 Summary

Based on the foregoing and recognizing the mapping accuracy of ±0.5 m, the HEC-2 model results are acceptable and can be used to delineate the flood risk areas with confidence.

5.6.2 Exshaw Creek

5.6.2.1 Initial Starting Conditions

The Exshaw Creek HEC-2 simulations were started at critical depth. Sensitivity of the computed water levels to the starting level was tested by decreasing the starting level by 0.3 m. The starting water level could not be increased by 0.3 m because the HEC-2 program automatically defaults to critical depth for supercritical runs if the specified starting level is greater than critical depth. Decreasing the starting water level by 0.3 m affected the water surface profile from Cross-Section 27 to 23,

Table 5-9
Sensitivity of Computed Water Levels to Variation in Channel Roughness, Bow River Reach

Change in Channel Mannings n	Mean Change in Computed Water Level (m)	Maximum Change in Computed Water Level (m)
+10%	0.10	0.19
-10%	-0.12	-0.16

Notes:

1) Based on 100 year flood profile

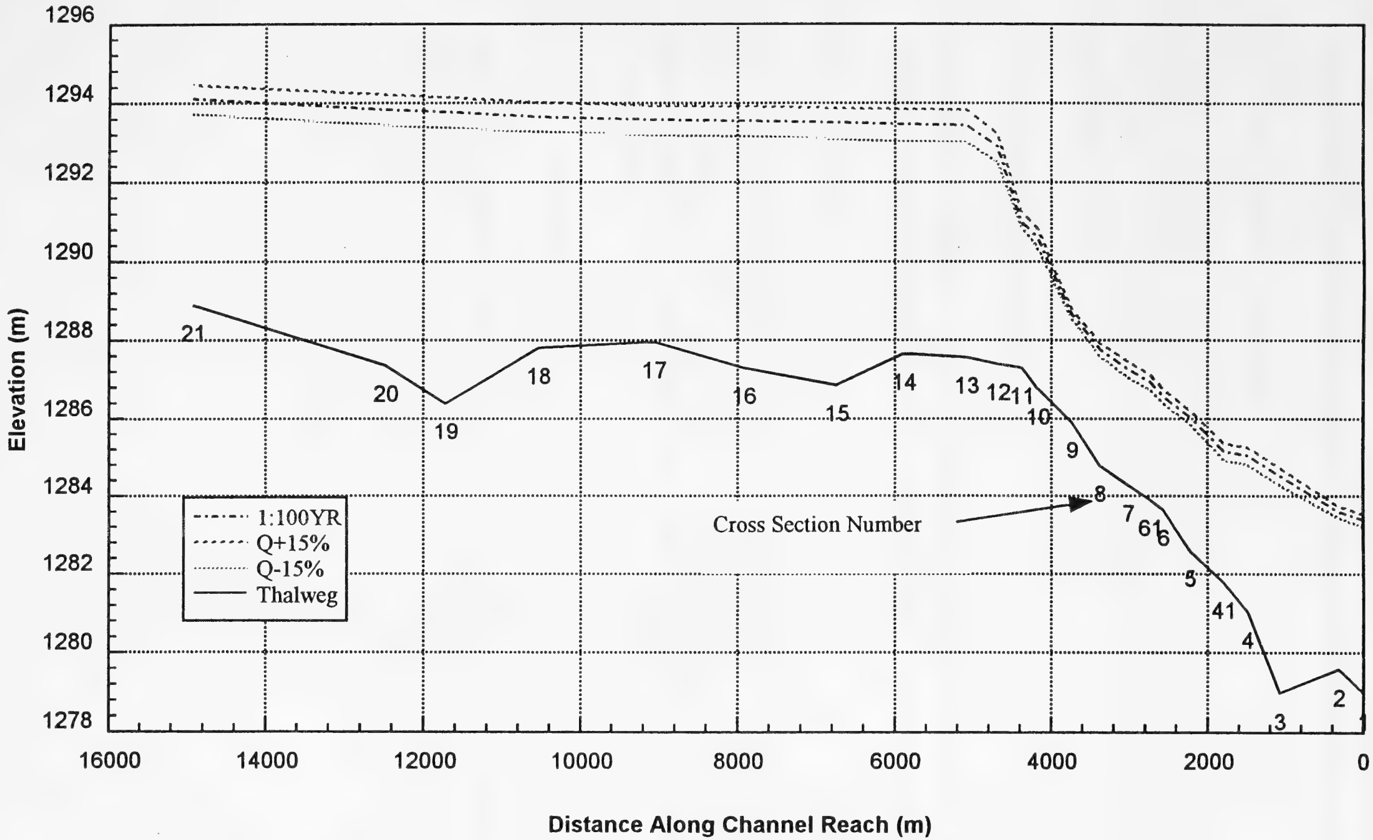

Figure 5-5

Sensitivity of Computed 100 Year Flood Profile to Changes in Discharge
Bow River Reach

thereafter no change was observed. The maximum change in water level was 0.3 m at Cross-section 27 and the change decayed rapidly in the downstream direction.

5.6.2.2 Main Channel Roughness

The channel Manning's n was varied by ±20% to determine the effect on the calculated water surface profiles and the results are presented in Table 5-10. The results show that the computed water levels are relatively insensitive to changes in channel Manning's n.

5.6.2.3 Floodplain Roughness

The floodplain roughness of Exshaw Creek does not effect the calculated 100 year water surface profile because the flow is contained within the main channel.

5.6.2.4 Discharge

The discharge used throughout the Exshaw Creek study reach was increased or decreased by 15% to determine the effect on the calculated water surface profile. The maximum change in water levels was 0.1 m, thus any reasonable error in discharge estimate is considered to have minimal effect on the predicted flood water elevations on Exshaw Creek.

5.6.2.5 Summary

Based on the foregoing, it may be concluded that the HEC-2 model for Exshaw Creek is reasonably accurate. However, Exshaw Creek is subject to significant scour and sediment deposition during floods, the effects of which are not modelled in HEC-2 which is a fixed-bed model. Also, during a flood, debris could quite easily block one of the small bridge openings. Either of these possibilities could lead to increased water levels above those predicted by HEC-2.

Table 5-10
Sensitivity of Computed Water Levels to Variation in Channel Roughness, Exshaw Creek

Change in Channel Mannings n	Mean Change in Computed Water Level (m)	Maximum Change in Computed Water Level (m)
+20%	0.04	0.15
-20%	-0.06	-0.17

Notes:

1) Based on 100 year flood profile

6 Floodway Determination

6 Floodway Determination

6.1 Terminology

The following definitions are defined in "Hydraulic Guidelines for Floodplain Delineation" by Alberta Environment, November 1990.

1) Floodway

The stream channel and that portion of the floodplain required to convey the design flood under a constricted condition. The floodway is narrower than the total flood risk zone therefore the water surface elevation must increase to carry the same flow. Floodway waters are deepest and fastest and are capable of the most destruction.

2) Flood Risk Area

The flood risk area is the area inundated by the design flood, in this case, a 100 year flood.

3) Flood Fringe

The portion of the floodplain between the floodway and the outer boundary outline of the design flood.

6.2 Floodway Criteria

The following general guidelines are based upon Alberta Environment Guidelines (1990) and project specific considerations for the Bow River and Exshaw Creek study reaches.

1) The water levels under floodway constricted conditions should not exceed the design flood water levels under natural or existing conditions by more than 0.3 m.

2) In general, all areas where the depth of flooding exceeds 1 m or the velocities are above 1 m/s, shall become a part of the floodway. However, in order to achieve a hydraulically smooth floodway boundary, some areas with depths exceeding 1 m and velocities exceeding 1 m/s will inevitably become part of the flood fringe.

3) In river reaches where the existing mean channel velocities are excessive, the encroachments for the floodway should be minimized so that the existing velocities are not further increased.

4) In reaches of supercritical flow no encroachment shall be introduced.

5) In the case of ice jam flooding, areas with depths of flooding of 1 m or more shall become a part of the floodway.

6.3 Methodology

The floodway in this study of the Bow River was determined by the following procedure.

1) The 100 year flood simulation was rerun activating the HEC-2 flow distribution option. The locations where the 1 m/s velocity criterion and the 1 m depth criterion first occur (going towards the river from the edges of the floodplain) were plotted on the floodway criteria maps.

2) A trial floodway boundary was delineated using the either the velocity or depth criterion (whichever results in the least constriction) on each side of the Bow River.

3) The flood simulation was repeated limiting conveyance with HEC-2's encroachment option to within the trial floodway boundaries. The location of the floodway boundaries were then checked against the revised velocities and depths.

4) The floodway boundaries on the floodway criteria maps were adjusted to make them hydraulically smooth.

5) The HEC-2 simulation of the 100 year flood contained within the adjusted floodway was compared to the 100 year flood simulation under existing conditions to ensure that the increase in depth did not exceed 0.3 m at any cross-section.

6) The resulting floodway boundaries were accepted to define the flood fringe and the floodway.

6.4 Results

The accepted floodway boundaries were delineated on the orthophoto maps and are illustrated on Drawings 11426-01 to 11426-06. Table 6-1 indicates the criteria governing the floodway limits for each cross-section and illustrates the water surface elevation difference under floodway restricted conditions. The increase in water level along the entire study reach did not exceed 0.05 m, well below the maximum 0.3 m rise criterion for determining floodway boundaries. The small increase in water level under floodway constricted conditions can be attributed to the small difference between the flood risk limits and the floodway boundary.

The 1 m depth criterion established the location of the floodway boundaries along the entire study reach. The 1 m/s velocity criterion coincided with the location of the 1 m depth criterion at some of the cross-sections. Smoothing of the floodway boundary along the study reach was minimal.

Table 6-1
Criteria Governing Floodway Limits, Bow River Reach

Cross Section Number	Water Level		Increase in Water Level (m)	Controlling Criteria for Determining Floodway Limits		
	Natural Condition (m)	Floodway Constriction (m)		Depth 1 m	Velocity 1 m/s	0.3 m Rise
1	1283.38	1283.38	0.00	R	L	
2	1283.60	1283.60	0.00	L,R		
3	1284.52	1284.52	0.00	L	R	
4	1285.04	1285.05	0.01	L,R	L,R	
4.1	1285.15	1285.15	0.00	L,R	L,R	
5	1286.03	1286.03	0.00	L,R	L,R	
6	1286.56	1286.56	0.00	L,R	R	
6.1	1286.93	1286.93	0.00	L,R	R	
7	1287.26	1287.26	0.00	L,R		
8	1287.76	1287.76	0.00	L,R		
9	1288.64	1288.68	0.04	L	R	
10	1290.59	1290.56	-0.03	L,R		
11	1290.98	1290.99	0.01	L,R	L,R	
12	1292.90	1292.93	0.03	L,R	L,R	
13	1293.45	1293.47	0.02	L,R		
14	1293.47	1293.49	0.02	L,R		

Cross Section Number	Water Level		Increase in Water Level (m)	Controlling Criteria for Determining Floodway Limits		
	Natural Condition (m)	Floodway Constriction (m)		Depth 1 m	Velocity 1 m/s	0.3 m Rise
15	1293.51	1293.53	0.02	L,R		
16	1293.56	1293.58	0.02	L,R		
17	1293.58	1293.60	0.02	L,R		
18	1293.66	1293.68	0.02	L,R		
19	1293.78	1293.80	0.02	L,R		
20	1293.84	1293.86	0.02	L,R		
21	1294.11	1294.12	0.01	L,R		

7 Flood Risk and Flood Frequency Maps

7 Flood Risk and Flood Frequency Maps

7.1 General

The orthophoto maps provided by Alberta Environmental Protection were used as a base map to produce the Flood Risk Maps and the Flood Frequency Maps. The 100 year flood risk area and floodway are shown on Drawings 11426-01 to 11426-03. The flood frequency mapping, Drawings 11426-04 to 11426-06 shows the areas that will be inundated by the 10 year and 100 year floods. The terms of reference for this study requested the delineation of the 50 year flood limit on the mapping but this could not be practically illustrated due to the proximity of the 100 year limits.

Mapping accuracy is ±0.5 metres vertical distance, whereas horizontal accuracy varies depending on the variation of the ground slope between contours.

7.2 Areas Affected by the Floodway

7.2.1 The Bow River Floodway

The floodway limits are denoted on Drawings 11426-01 to 11426-03 by dashed lines or by solid lines where the floodway coincides with the flood risk limit. The floodway limit is defined by the 1 metre depth criteria over most of the Bow River study reach. In the reach upstream of Lac des Arcs almost all of the floodplain area is included in the floodway. The Exshaw Industrial Park is outside of the floodway limits. Lac des Arcs and the new dykes fall within the floodway due to the depth of water in this reach. Within the reach from Lac des Arcs to Exshaw Creek the floodway is confined within the main channel by the high banks in this area. Downstream of Exshaw Creek where the Bow River floodplain widens the floodway again covers most of the floodplain.

7.2.2 The Exshaw Creek Floodway

The HEC-2 simulations indicate that Exshaw Creek will not overflow its banks during a 100 year flood, thus the flood limits are at the top-of-banks. Since the flood limits are at the top of banks and the creek flows supercritical a floodway analysis was not performed for Exshaw Creek.

Sediment and debris flows were not considered as part of this study. However, if sediment or debris accumulations cause infilling of the channel, or blockage of the

bridge openings, it is possible the creek could overflow its banks during a major flood. If this were to happen, the flow would probably establish a new channel in the alluvial fan material on either side of the existing channel. A few buildings close to the creek may be affected by overland flow if the channel were to shift course.

7.3 Areas Affected by the Flood Fringe

The flood fringe is the area between the floodway limits and the flood risk limits, and is shown on Drawings 11426-01 to 11426-03. The 100 year flood would not affect any developed areas other than the Exshaw Industrial Park situated near the sewage treatment facilities for Exshaw. There are a few buildings in this area that would suffer flood water depths of approximately 0.5 metres. The banks for the sewage lagoon are higher than the predicted water elevation thus the lagoon would not be effected by the 100 year flood.

The Exshaw Industrial Park suffers frequent flooding from Jura Creek (not investigated in this study) which tends to overflow its banks due to blockage of the channel by large amounts of sediment. To minimize the flooding problem, the M.D. of Bighorn is in the process of obtaining approval to reroute the creek around the industrial park.

The major transportation routes in the M.D. of Bighorn have low areas that would be inundated during a 100 year flood event, as follows:

A short length of Highway 1 (Trans Canada Highway) at the upstream end of Lac des Arcs would be inundated to a maximum depth of less than 1 metre.

The CPR tracks across from Lac des Arcs and at Gap Lake would be flooded up to a depth of 1.0 metres.

Highway 1A has a short length near the cement plant that could be slightly inundated. The depth of water is about 0.1 metres, which is within the accuracy of the predicted flood levels.

Thus, during a 100 year flood all the overland transportation routes through the Bow River valley would be flooded.

7.4 Flood Frequency Maps

Flood frequency maps are given in Drawings 11426-04 to 11426-06. These show the flood risk limits for the 10 and 100 year flood events for existing conditions with the dykes at Lac des Arcs. These maps delineate the difference in the extent of flooding anticipated for the 10 and 100 year flood events.

There are only small differences between the 10 and 100 year flood limits. Most of the floodplain area would be inundated in a 10 year flood event. The maps show that the Exshaw Industrial Park would be flooded even in the 10 year flood event though the water depth would not be as great.

Highways 1 and 1A are accessible during the 10 year flood event and are marginally above the predicted water levels for the 50 year flood event. The low sections of the CPR tracks are just above the 10 year flood water levels, but would be submerged during a 50 year flood event.

8 References

8 References

1. Alberta Environment (1977), "Canmore Flood Protection Proposal Study and Report"

2. Alberta Environment (1990), "Hydrologic and Hydraulic Guidelines for Floodplain Delineation," Flood Damage Reduction Program, Publication #1.

3. Alberta Environmental Protection (1994), "Flood Frequency Analyses Bow River Floodplain Study".

4. Arcement, G.J. Jr. and Schneider, V.R. (1984), "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains", U.S. Geological Survey.

5. Chow, V.T. (1959), "Open Channel Hydraulics", McGraw-Hill Book Company.

6. Scott and Associates Engineering Limited (1993), "Lac des Arcs and Exshaw Beach Dust Control Program, Preliminary Design Report", prepared for M.D. of Bighorn No. 8.

7. W-E-R Agra Ltd. (1993), "Canmore Flood Risk Mapping Study".

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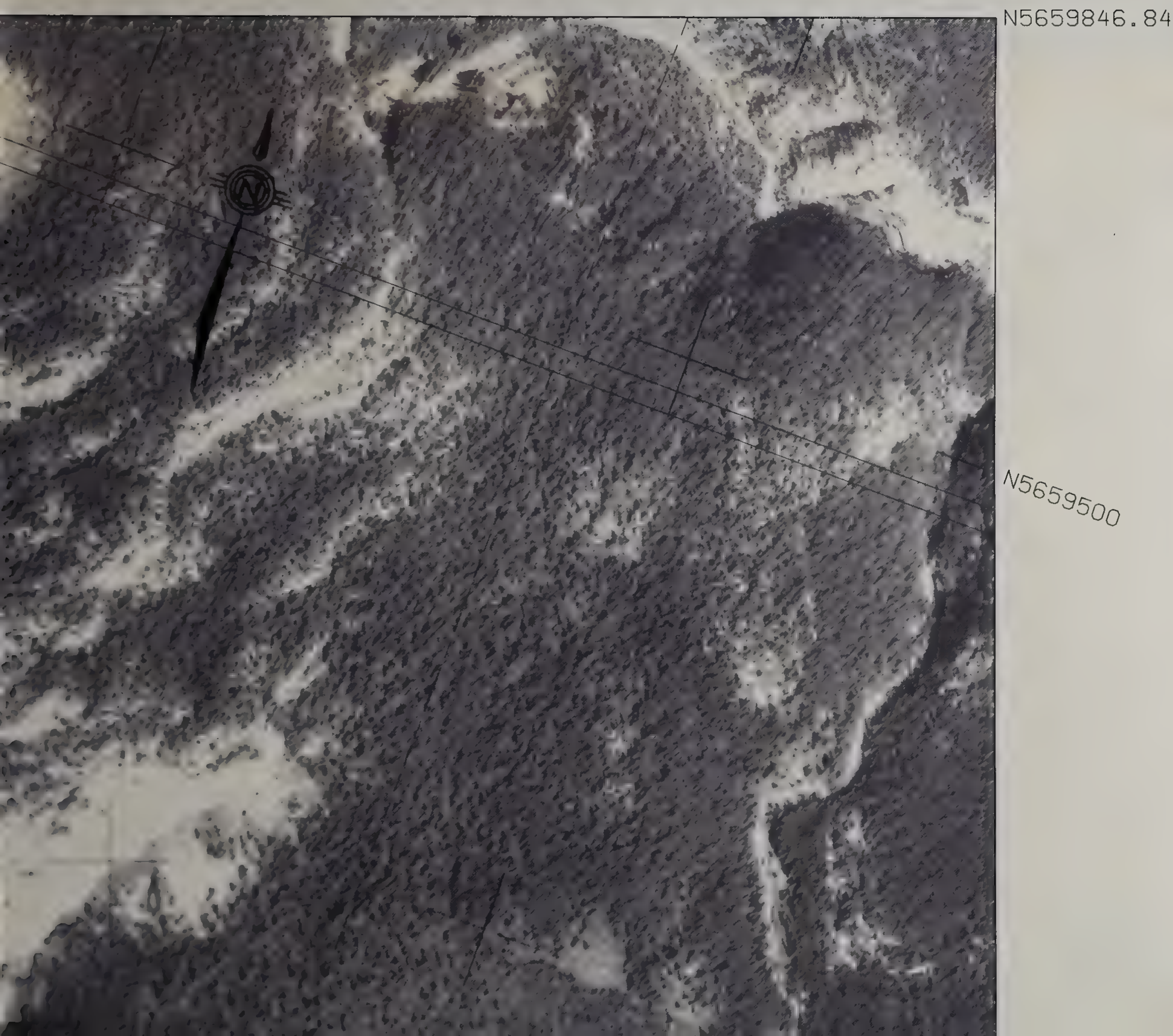


Flood Risk Map

Notes:

1) Man-made inlet channel replaced by dyke inlet structure with a 1.2 m diameter gated corrugated steel pipe and a 0.6 m non-gated elliptical corrugated steel pipe.

2) Dyke constructed to elevation 1292.0 m.

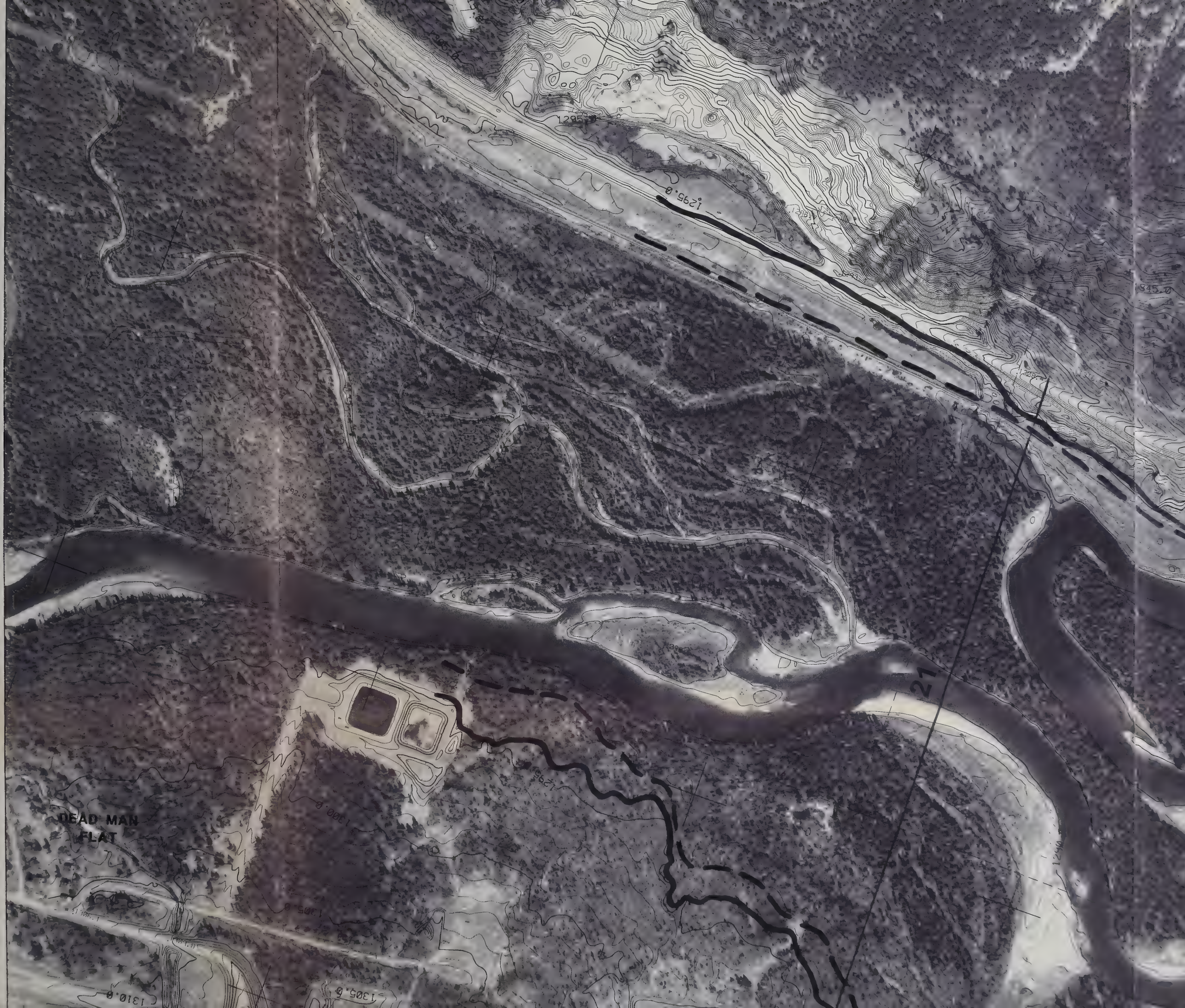
3) Dyke constructed to elevation 1292.0 m with one gated 1.2 m diameter corrugated steel pipe and five 1.2 m diameter elliptical non-gated culverts.

4) Base maps were provided by Alberta Environmental Protection.

5) The flood risk boundaries along the Bow River were delineated using the computed water levels under floodway constricted conditions. The following table presents these water levels.

Bow River

Cross Section Number	Water Level (m)
1	1283.4
2	1283.6
3	1284.5
4	1285.0


DEAD MAN
FLAT
21


HIGHWAY 1A
GAP LAKE
CANADIAN PACIFIC RAILWAY
BOW
RIVER
19
20
1315.0
1310.0
1290.0

4	1285.0
5	1286.0
6	1286.6
7	1287.3
8	1287.8
9	1288.7
10	1290.6
11	1291.0
12	1292.9
13	1293.5
14	1293.5
15	1293.5
16	1293.6
17	1293.6
18	1293.7
19	1293.8
20	1293.9
21	1294.1

6) The flood risk boundaries along Exshaw Creek were delineated at the top-of-banks because the computed 1:100 year flood levels were all within banks. The following table presents the water levels for the 1:100 year flood on Exshaw Creek under existing conditions.

Exshaw Creek

Cross Section Number	Water Level (m)
1	1291.5
2	1292.7
3	1293.8
4	1294.3
5	1295.1
6	1295.9
7	1297.4
8	1299.3
9	1301.5
10	1303.6
11	1304.7
12	1304.8
13	1307.1
14	1309.2
15	1311.4
16	1314.6
17	1316.8
18	1319.4
19	1321.6
20	1324.4
21	1326.1
22	1326.8
23	1326.7
24	1328.4

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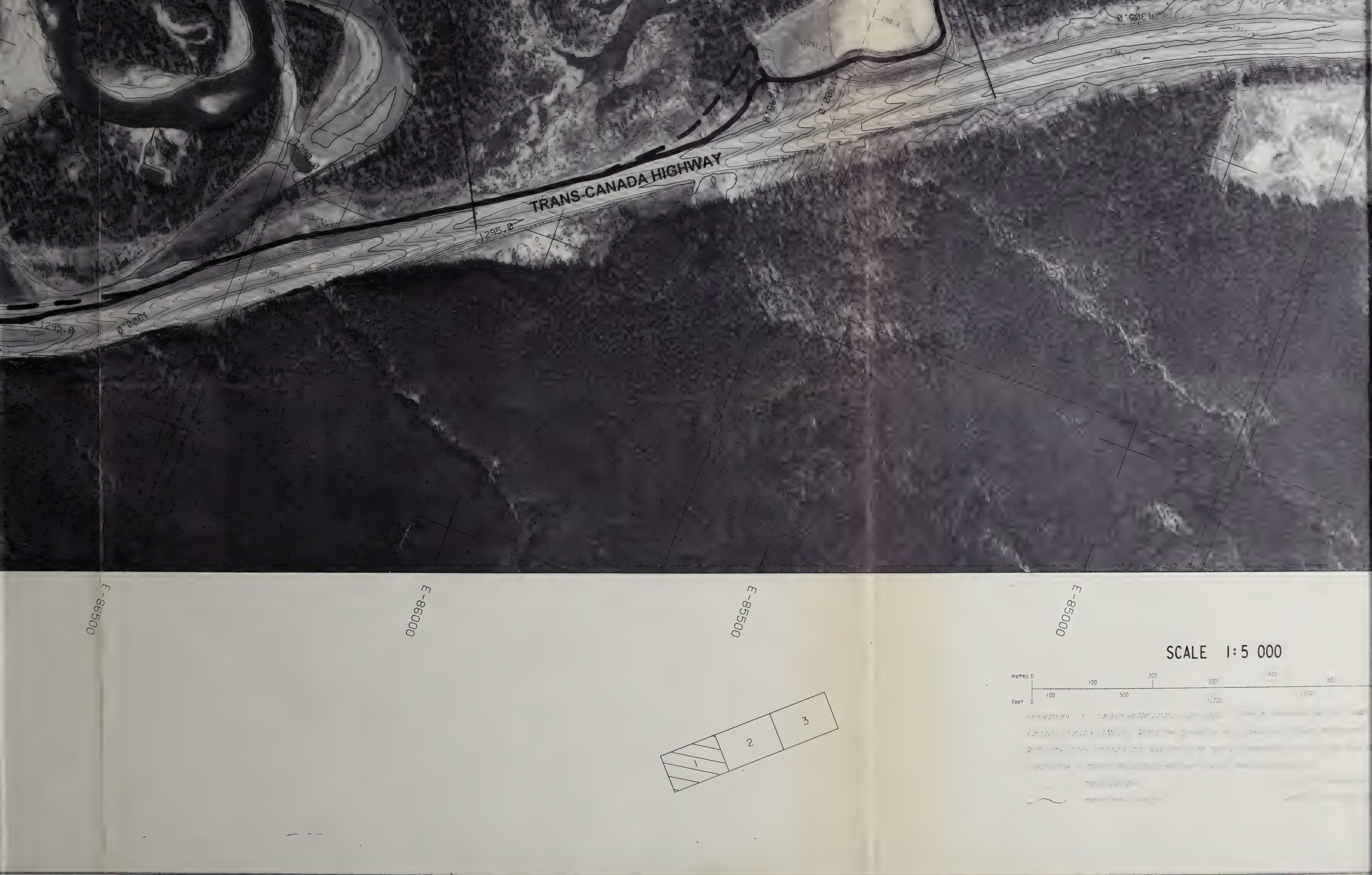
DAMAGE
REDUCTION
PROGRAM

Environment Canada Environnement Canada

Alberta
ENVIRONMENTAL PROTECTION


TRANS-CANADA HIGHWAY
1295.0
1300.0
E-86500
E-86000
E-85500
E-85000
SCALE 1:5 000
metres 0
100
200
300
feet 0
100
500
1,000
1
2
3

15	1311.4
16	1314.6
17	1316.8
18	1319.4
19	1321.6
20	1324.4
21	1326.1
22	1326.8
23	1326.7
24	1328.4
25	1330.7
26	1333.4
27	1335.8

Legend:

- Flood risk limit of the 100 year flood
- Floodway limit of the 100 year flood
- 18 — Cross section number and location
- Flow direction
- Dyke center line

SCALE 1:5 000

200 300 400 500 600 metres

500 1,000 1,500 2,000 feet

...ansverse Mercator, Scale factor 0.9999 at Reference Meridian 114°

...Where the ground is fully obscured, contours are dashed.

...are less than 5 mm apart, intermediate contours have been dropped.

...mean sea level, North American Datum, 1927

Depression contour

.1082.6 Spot height in metres

BIGHORN / BOW RIVER

Orthophoto MAY 1993
Contours MAY 1993

1994

DATE	NO.	REVISIONS	CH	APP	APP

ACRES

ALBERTA ENVIRONMENTAL PROTECTION

BOW RIVER - M.D. OF BIGHORN

FLOOD RISK MAPPING STUDY

ACRES INTERNATIONAL LIMITED

DESIGN
PREPARED M. DONEGAN
CHECKED A. BRELAND

DRAWING
PREPARED G. TYOMKIN
CHECKED C. ANDERSON

PROJECT ENGINEER
M. NOZDRYN-PLOTNICKI

PROJECT MANAGER
D. ROBERTS

FLOOD RISK MAP FOR THE 100 YEAR FLOOD SHEET 1 OF 3

SCALE: 1:5000

ACRES PROJECT NO. P11426.00

DRAWING NO 11426-01

REV A


HIGHWAY 1A
CANADIAN PACIFIC RAILWAY
1345.0
1340.0
1335.0
1330.0
1325.0
1305.0
1300.0


BOW
RIVER
16
SEE NOTE 2
1300.0
1290.0
1330.0
1325.0
1305.0

<u>**Flood Risk Map**</u>

Notes:

1) Man-made inlet channel replaced by dyke inlet structure with a 1.2 m diameter gated corrugated steel pipe and a 0.6 m non-gated elliptical corrugated steel pipe

2) Dyke constructed to elevation 1292.0 m.

3) Dyke constructed to elevation 1292.0 m with one gated 1.2 m diameter corrugated steel pipe and five 1.2 m diameter elliptical non-gated culverts.

4) Base maps were provided by Alberta Environmental Protection.

5) The flood risk boundaries along the Bow River were delineated using the computed water levels under floodway constricted conditions. The following table presents these water levels.

<u>Bow River</u>

Cross Section Number	Water Level (m)
1	1283.4
2	1283.6
3	1284.5
4	1285.0
5	1286.0
6	1286.6
7	1287.3


CANADIAN
1290.0
1298.0
1290.0
17
NOTE 1
1305.0
TRANS-CANADA HIGHWAY
1290.0


SEE NOTE 1
LAC DES ARCS
SEE NOTE 3
CEMENT PLAN
15
14
13
1290.0
1300.0
1305.0
1310.0
1325.0
1335.0
1340.0
1380.0
1390.0
1410.0
1420.0

6	1286.6
7	1287.3
8	1287.8
9	1288.7
10	1290.6
11	1291.0
12	1292.9
13	1293.5
14	1293.5
15	1293.5
16	1293.6
17	1293.6
18	1293.7
19	1293.8
20	1293.9
21	1294.1

6) The flood risk boundaries along Exshaw Creek were delineated at the top-of-banks because the computed 1:100 year flood levels were all within banks. The following table presents the water levels for the 1:100 year flood on Exshaw Creek under existing conditions.

Exshaw Creek

Cross Section Number	Water Level (m)
1	1291.5
2	1292.7
3	1293.8
4	1294.3
5	1295.1
6	1295.9
7	1297.4
8	1299.3
9	1301.5
10	1303.6
11	1304.7
12	1304.8
13	1307.1
14	1309.2
15	1311.4
16	1314.6
17	1316.8
18	1319.4
19	1321.6
20	1324.4
21	1326.1
22	1326.8
23	1326.7
24	1328.4
25	1330.7
26	1333.4
27	1335.8

E-84784.15 E-84500 E-84000 E-83500

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DAMAGE
REDUCTION
PROGRAM

Environment Canada
Environnement Canada

Alberta
ENVIRONMENTAL PROTECTION

CADD FILE: 11426-TB.DWG LAST PLOT DATE: DEC 11/95

SEE NOTE 3
CAMPGROUND
13
1290.0
1295.0
1300.0
1305.0
E-83500
E-83000
E-82500
E-82000
E-81500
SCALE 1:5
1
2
3

SCALE 1:5 000

18	1319.4
19	1321.6
20	1324.4
21	1326.1
22	1326.8
23	1326.7
24	1328.4
25	1330.7
26	1333.4
27	1335.8

Legend:

- Flood risk limit of the 100 year flood
- Floodway limit of the 100 year flood
- 13 Cross section number and location
- Flow direction
- Dyke center line

BIGHORN / BOW RIVER

Orthophoto MAY 1993
Contours MAY 1993

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES

ALBERTA ENVIRONMENTAL PROTECTION
BOW RIVER - M.D. OF BIGHORN
FLOOD RISK MAPPING STUDY

ACRES INTERNATIONAL LIMITED

DESIGN
PREPARED M. DONEGAN
CHECKED A. BRELAND

DRAWING
PREPARED G. TYOMKIN
CHECKED C. ANDERSON

PROJECT ENGINEER
M. NOZDRYN–PLOTNICKI

PROJECT MANAGER
D. ROBERTS

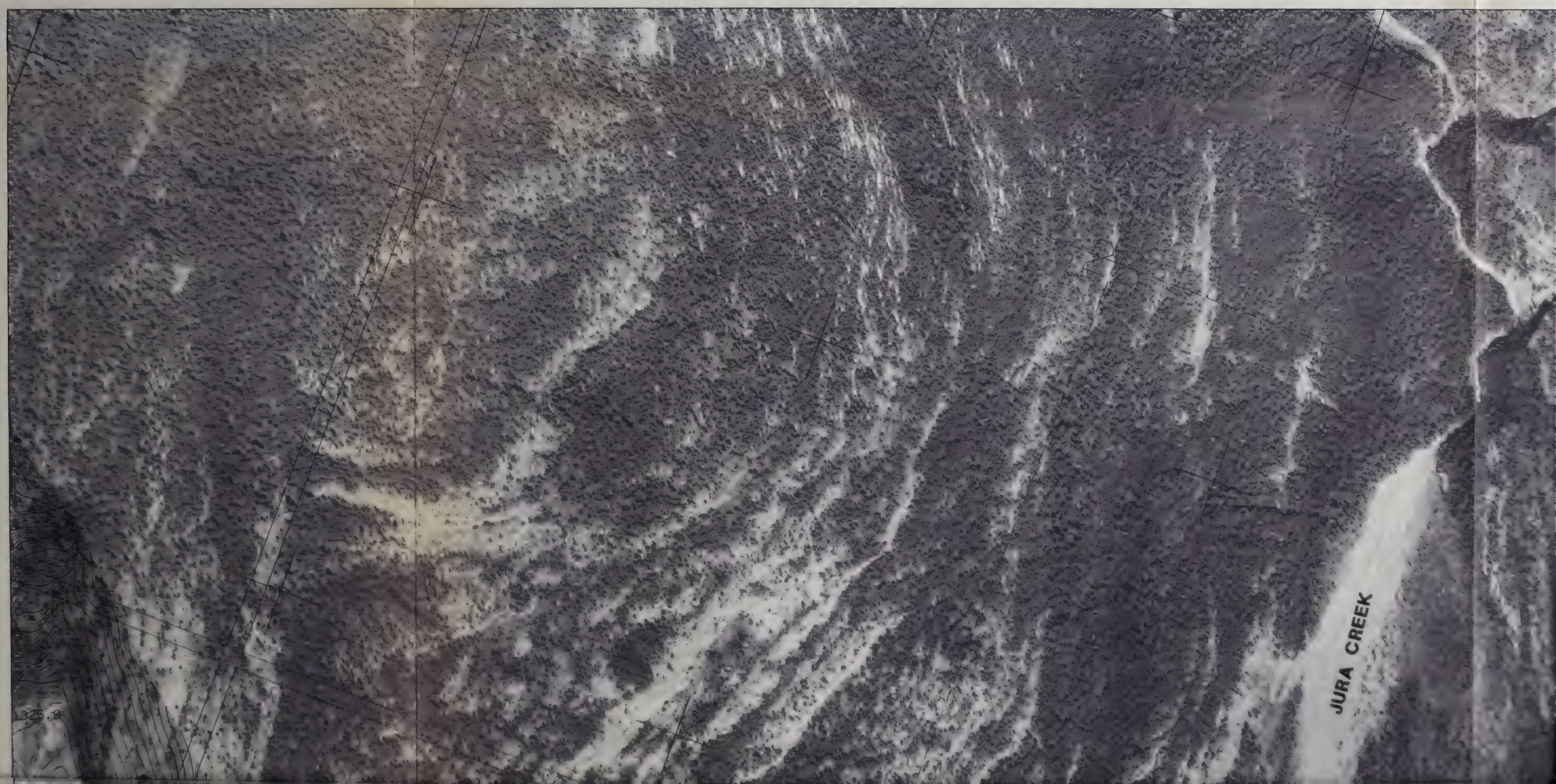
FLOOD RISK MAP FOR THE 100 YEAR FLOOD SHEET 2 OF 3

SCALE: 1:5000

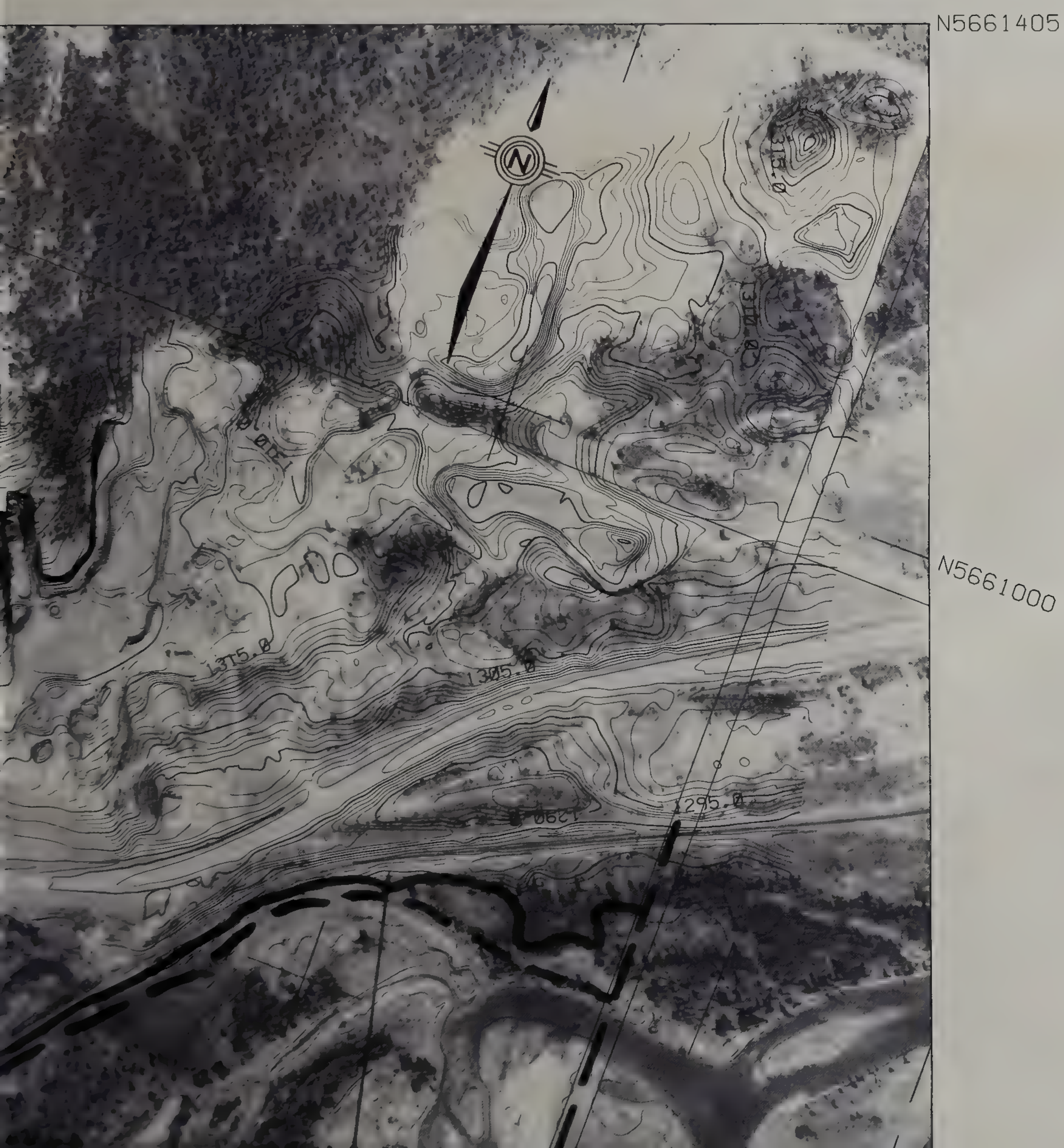
ACRES PROJECT NO. **P11426.00**

DRAWING NO.: 11426-02

REV A


325.8
JURA CREEK

JURA CREEK
KANANASKIS
1320.0
1315.0
1305.
1285.0
1289.6
1395.



Flood Risk Map

Notes:

1) Man-made inlet channel replaced by dyke inlet structure with a 1.2 m diameter gated corrugated steel pipe and a 0.6 m non-gated elliptical corrugated steel pipe.

2) Dyke constructed to elevation 1292.0 m.

3) Dyke constructed to elevation 1292.0 m with one gated 1.2 m diameter corrugated steel pipe and five 1.2 m diameter elliptical non-gated culverts.

4) Base maps were provided by Alberta Environmental Protection.

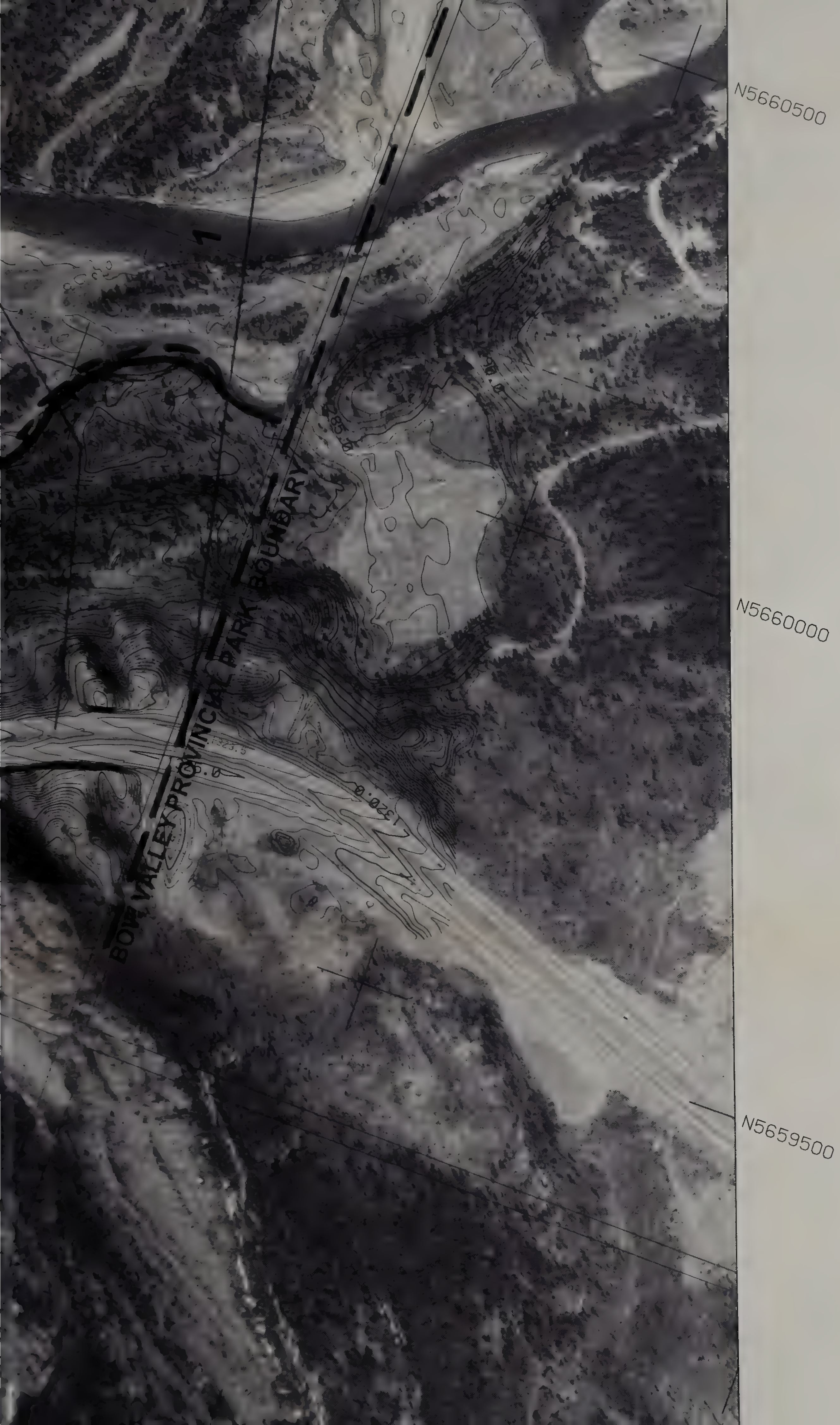
5) The flood risk boundaries along the Bow River were delineated using the computed water levels under floodway constricted conditions. The following table presents these water levels.

Bow River

Cross Section Number	Water Level (m)
1	1283.4
2	1283.6
3	1284.5
4	1285.0
5	1286.0
6	1286.6
7	1287.3
8	1287.8
9	1288.7
10	1290.6
11	1291.0
12	1292.9
13	1293.5

EXSHAW CREEK
EXSHAW
HIGHWAY 1A
CANADIAN PACIFIC RAILWAY
EXSHAW INDUSTRIAL PARK
SEWAGE TREATMENT
PLANT
BOW RIVER
E 15
E 10
E 5
E 1
11
10
9
8
9

LIME PLANT
TRANS-CANADA HIGHWAY
BOW RIVER
BOW VALLEY PROVINCIAL PARK BOUNDARY
1
2
3
4
5



12	1292.9
13	1293.5
14	1293.5
15	1293.5
16	1293.6
17	1293.6
18	1293.7
19	1293.8
20	1293.9
21	1294.1

6) The flood risk boundaries along Exshaw Creek were delineated at the top-of-banks because the computed 1:100 year flood levels were all within banks. The following table presents the water levels for the 1:100 year flood on Exshaw Creek under existing conditions.

Exshaw Creek

Cross Section Number	Water Level (m)
1	1291.5
2	1292.7
3	1293.8
4	1294.3
5	1295.1
6	1295.9
7	1297.4
8	1299.3
9	1301.5
10	1303.6
11	1304.7
12	1304.8
13	1307.1
14	1309.2
15	1311.4
16	1314.6
17	1316.8
18	1319.4
19	1321.6
20	1324.4
21	1326.1
22	1326.8
23	1326.7
24	1328.4
25	1330.7
26	1333.4
27	1335.8

Legend:

Flood risk limit of the 100 year flood

Floodway limit of the 100 year flood

5 Cross section number and location

LAST PLOT DATE DEC 11/95

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REDUCTION
PROGRAM

Environment Canada
Environnement Canada

Alberta
ENVIRONMENTAL PROTECTION

SCALE 1:5 000

metres 0 100 200 300 400 500

feet 0 100 500 1000 1500

Projection: ... Transverse Mercator ...

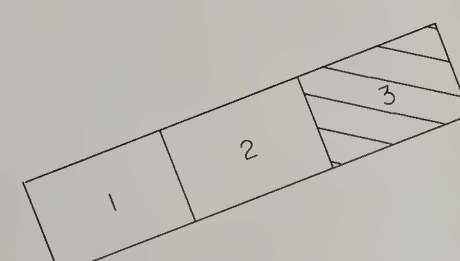
Contour interval: 1 METRE ... Where the ground ...

Where the index contours are less ...

Elevations: in metres above mean sea ...

metre contour

metre index contour



25	1330.7
26	1333.4
27	1335.8

Legend:

- Flood risk limit of the 100 year flood
- Floodway limit of the 100 year flood
- 5 — Cross section number and location
- Flow direction
- Dyke center line

SCALE 1:5 000

200 300 400 500 600 metres

1,000 1,500 2,000 feet

...se Mercator, Scale factor 0.9999 at Reference Meridian 114°

... 1 METRE Where the ground is fully obscured, contours are dashed.

... contours are less than 5 mm apart, intermediate contours have been dropped.

... above mean sea level, North American Datum, 1927

Depression contour

.1082.6 Spot height in metres

BIGHORN / BOW RIVER

Orthophoto MAY 1993
Contours MAY 1993

DATE	NO.	REVISIONS	CH	APP	APP

ACRES

ALBERTA ENVIRONMENTAL PROTECTION

BOW RIVER - M.D. OF BIGHORN

FLOOD RISK MAPPING STUDY

ACRES INTERNATIONAL LIMITED

DESIGN
PREPARED M. DONEGAN
CHECKED A. BRELAND

DRAWING
PREPARED G. TYOMKIN
CHECKED C. ANDERSON

PROJECT ENGINEER
M. NOZDRYN-PLOTNICKI

PROJECT MANAGER
D. ROBERTS

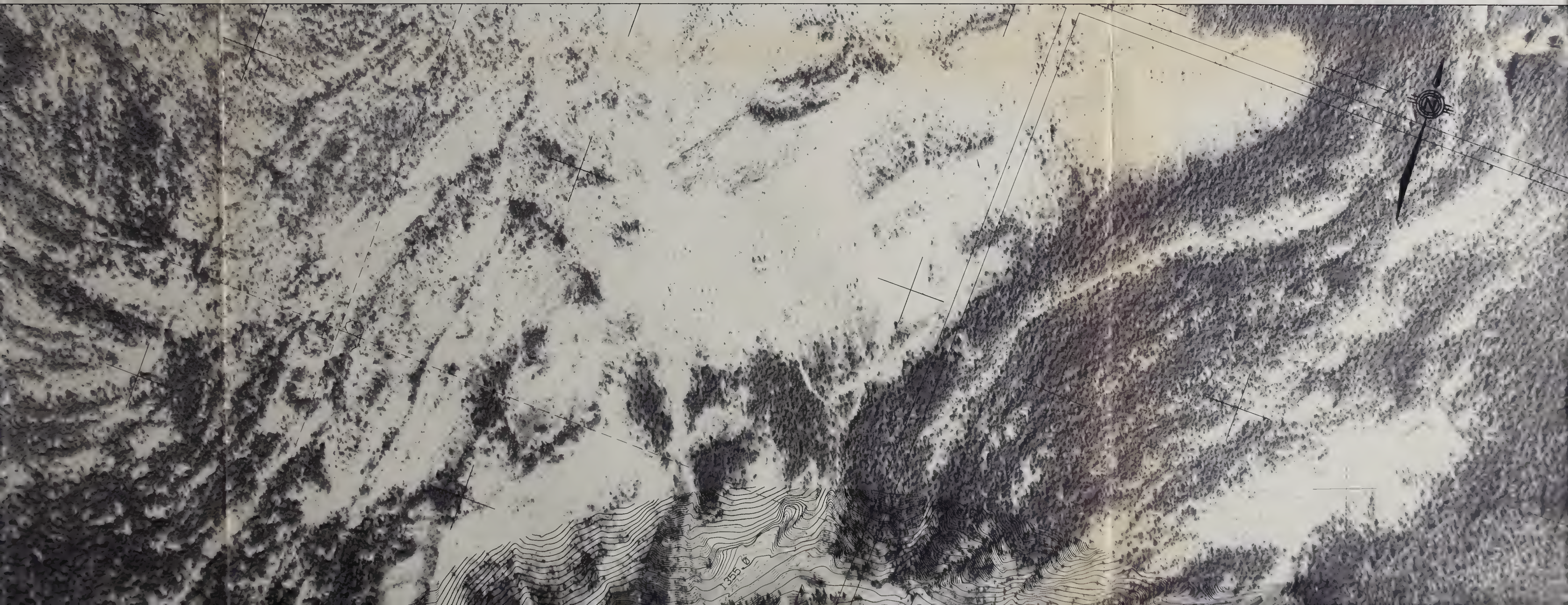
FLOOD RISK MAP FOR THE 100 YEAR FLOOD SHEET 3 OF 3

SCALE: 1:5000

ACRES PROJECT NO. P11426.00

DRAWING NO. 11426-03

REV A



355.Ø

Flood Frequency Map

Notes:

1) Man-made inlet channel replaced by dyke inlet structure with a 1.2 m diameter gated corrugated steel pipe and a 0.6 m non-gated elliptical corrugated steel pipe.

2) Dyke constructed to elevation 1292.0 m.

3) Dyke constructed to elevation 1292.0 m with one gated 1.2 m diameter corrugated steel pipe and five 1.2 m diameter elliptical non-gated culverts.

4) Base maps were provided by Alberta Environmental Protection

5) The 10 and 100 year flood risk boundaries along the Bow River were delineated using the computed water levels under natural conditions. The following table presents these water levels.

Bow River

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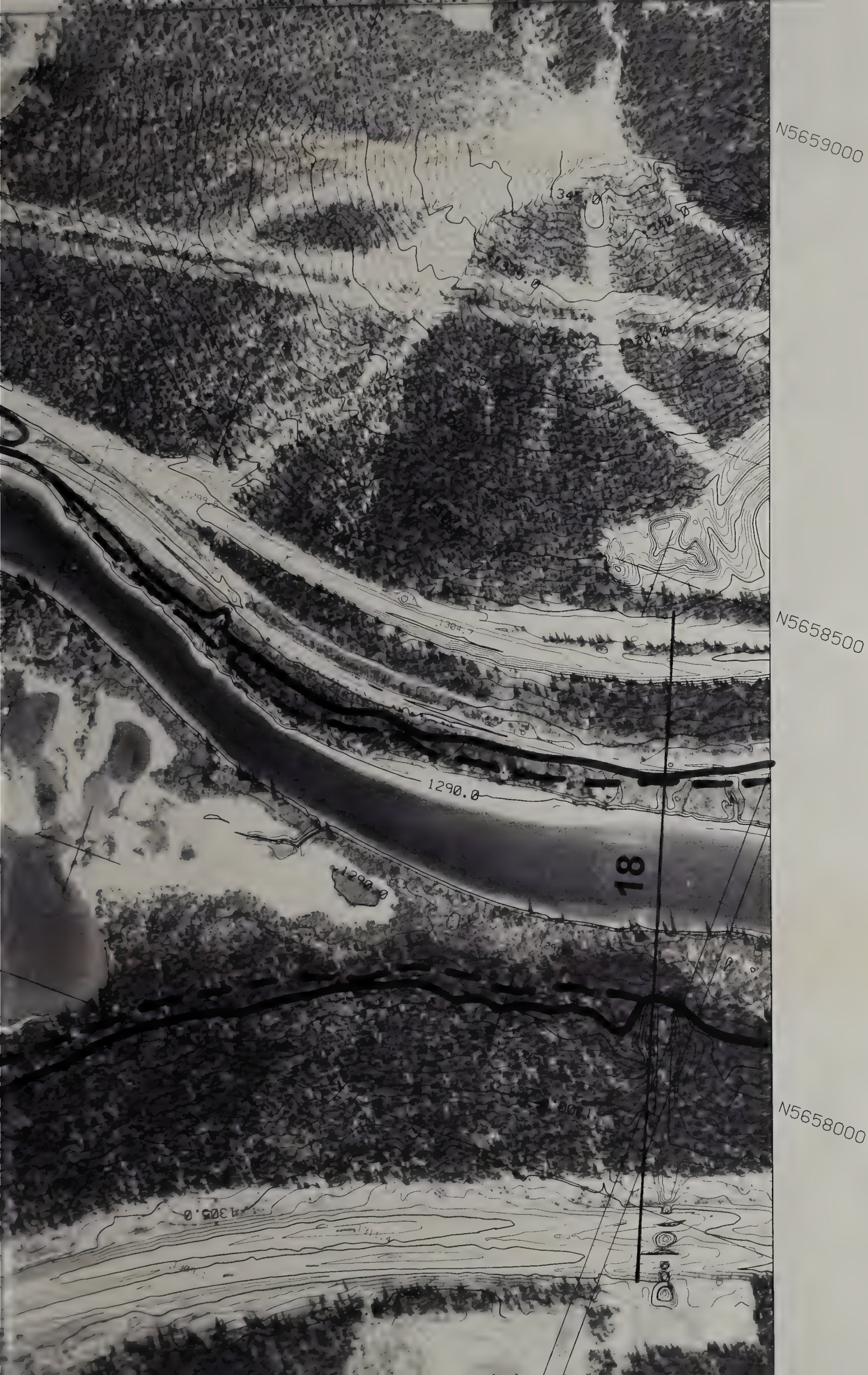
1	1283.4	1283.0
2	1283.6	1283.2
3	1284.5	1284.0
4	1285.0	1284.5
5	1286.0	1285.6
6	1286.6	1286.1
7	1287.3	1286.8
8	1287.8	1287.4


DEAD MAN
FLAT

HIGHWAY 1A
GAP LAKE
CANADIAN PACIFIC RAILWAY
BOW
RIVER
19
20
1315.0
1310.0
1355.0
1300.0
1325.0
1320.0
1315.0
1295.0
1290.0
1305.0
1291.2



6	1286.6	1286.1
7	1287.3	1286.8
8	1287.8	1287.4
9	1288.6	1288.3
10	1290.6	1290.0
11	1291.0	1290.6
12	1292.9	1292.0
13	1293.4	1292.4
14	1293.5	1292.4
15	1293.5	1292.6
16	1293.6	1292.7
17	1293.6	1292.7
18	1293.7	1292.8
19	1293.8	1292.9
20	1293.8	1292.9
21	1294.1	1293.2

Legend:

Flood risk limit of the 100 year flood

Flood risk limit of the 10 year flood

E-88093.23 E-88000 E-87500 E-87000 E-86500

Canada-Alberta
FLOOD
DAMAGE
REDUCTION
PROGRAM

Environment Canada Environnement Canada

Alberta
ENVIRONMENTAL PROTECTION

CADD FILE: 11426-TB.DWG LAST PLOT DATE: DEC 11/95

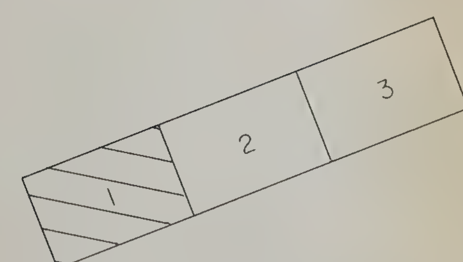
E-86500

E-86000

E-85500

E-85000

SCALE 1:5 000



SCALE 1:5 000

0 100 200 300 400 500 600 metres

0 500 1,000 1,500 2,000 feet

114°

BIGHORN /
BOW RIVER

Orthophoto MAY 1993
Contours MAY 1993

Legend:

- Flood risk limit of the 100 year flood
- Flood risk limit of the 10 year flood
- 18 — Cross section number and location
- Flow direction
- Dyke center line

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES

ALBERTA ENVIRONMENTAL PROTECTION

BOW RIVER - M.D. OF BIGHORN

FLOOD RISK MAPPING STUDY

ACRES INTERNATIONAL LIMITED

DESIGN
PREPARED M. DONEGAN
CHECKED A. BRELAND

DRAWING
PREPARED G. TYOMKIN
CHECKED C. ANDERSON

PROJECT ENGINEER
M. NOZDRYN-PLOTNICKI

PROJECT MANAGER
D. ROBERTS

FLOOD FREQUENCY MAP
SHEET 1 OF 3

SCALE: 1:5000

ACRES PROJECT NO. **P11426.00**

DRAWING NO.: 11426-04

REV A

1345.0
1340.0
1335.0
1330.0
1305.0
HIGHWAY 1A
ANADIAN PACIFIC RAILWAY


BOW
RIVER
16
1300.0
1290.0
1330.0
1325.0
1305.0
N

Flood Frequency Map

Notes:

1) Man-made inlet channel replaced by dyke inlet structure with a 1.2 m diameter gated corrugated steel pipe and a 0.6 m non-gated elliptical corrugated steel pipe.

2) Dyke constructed to elevation 1292.0 m.

3) Dyke constructed to elevation 1292.0 m with one gated 1.2 m diameter corrugated steel pipe and five 1.2 m diameter elliptical non-gated culverts.

4) Base maps were provided by Alberta Environmental Protection.

5) The 10 and 100 year flood risk boundaries along the Bow River were delineated using the computed water levels under natural conditions. The following table presents these water levels.

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4	1285.0	1284.5
5	1286.0	1285.6
6	1286.6	1286.1
7	1287.3	1286.8

CANADIAN
1290.0
SEE NOTE
17
TRANS-CANADA HIGHWAY
1305.0


NOTE 1
LAC DES ARCS
SEE NOTE 3
CEMENT PLANT
15
14
13
E 27
E 25
1290.0
1300.0
1310.0
1325.0
1305.0

7	1287.3	1286.8
8	1287.8	1287.4
9	1288.6	1288.3
10	1290.6	1290.0
11	1291.0	1290.6
12	1292.9	1292.0
13	1293.4	1292.4
14	1293.5	1292.4
15	1293.5	1292.6
16	1293.6	1292.7
17	1293.6	1292.7
18	1293.7	1292.8
19	1293.8	1292.9
20	1293.8	1292.9
21	1294.1	1293.2

Legend:

Flood risk limit of the 100 year flood

Flood risk limit of the 10 year flood

E-84784.15 E-84500 E-84000 E-83500

Canada-Alberta
FLOOD
DAMAGE
REDUCTION
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Environment Canada
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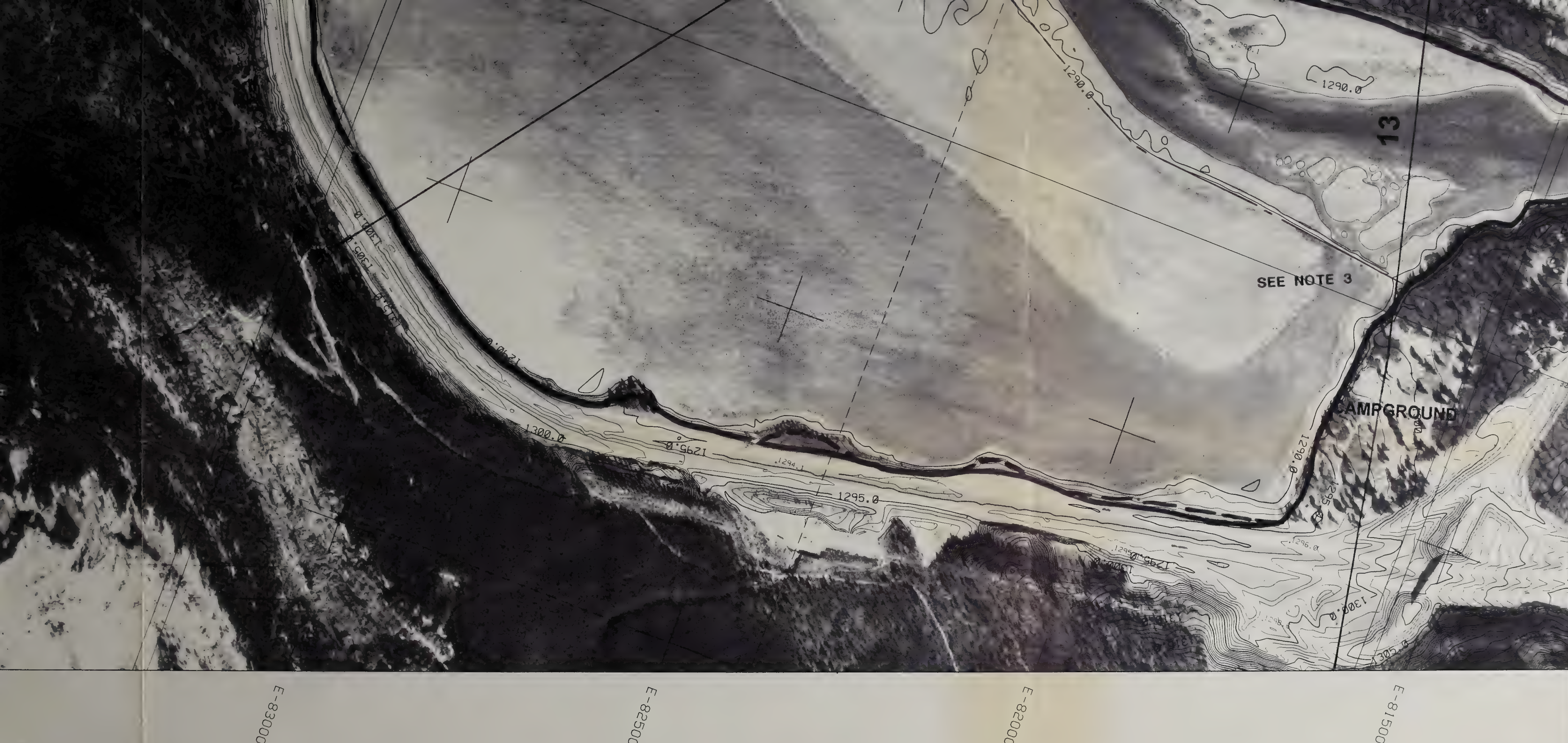
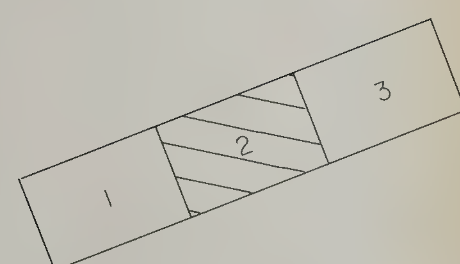

1290.0
1290.0
13
SEE NOTE 3
CAMPGROUND
1300.0
1295.0
1295.0
1290.0
1300.0
E-83000
E-82500
E-82000
E-81500

SCALE 1:5 000


1
2
3

N5657492.35

E-81500

E-81025.35

SCALE 1:5 000

200 300 400 500 600 metres

1,000 1,500 2,000 feet

114°

Depression contour

Legend:

- Flood risk limit of the 100 year flood
- Flood risk limit of the 10 year flood
- 13 — Cross section number and location
- Flow direction
- Dyke center line

BIGHORN / BOW RIVER

Ortnophoto MAY 1993
Contours MAY 1993

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ACRES

ALBERTA ENVIRONMENTAL PROTECTION

BOW RIVER - M.D. OF BIGHORN

FLOOD RISK MAPPING STUDY

ACRES INTERNATIONAL LIMITED

DESIGN
PREPARED M. DONEGAN
CHECKED A. BRELAND

DRAWING
PREPARED G. TYOMKIN
CHECKED C. ANDERSON

PROJECT ENGINEER
M. NOZDRYN-PLOTNICKI

PROJECT MANAGER
D. ROBERTS

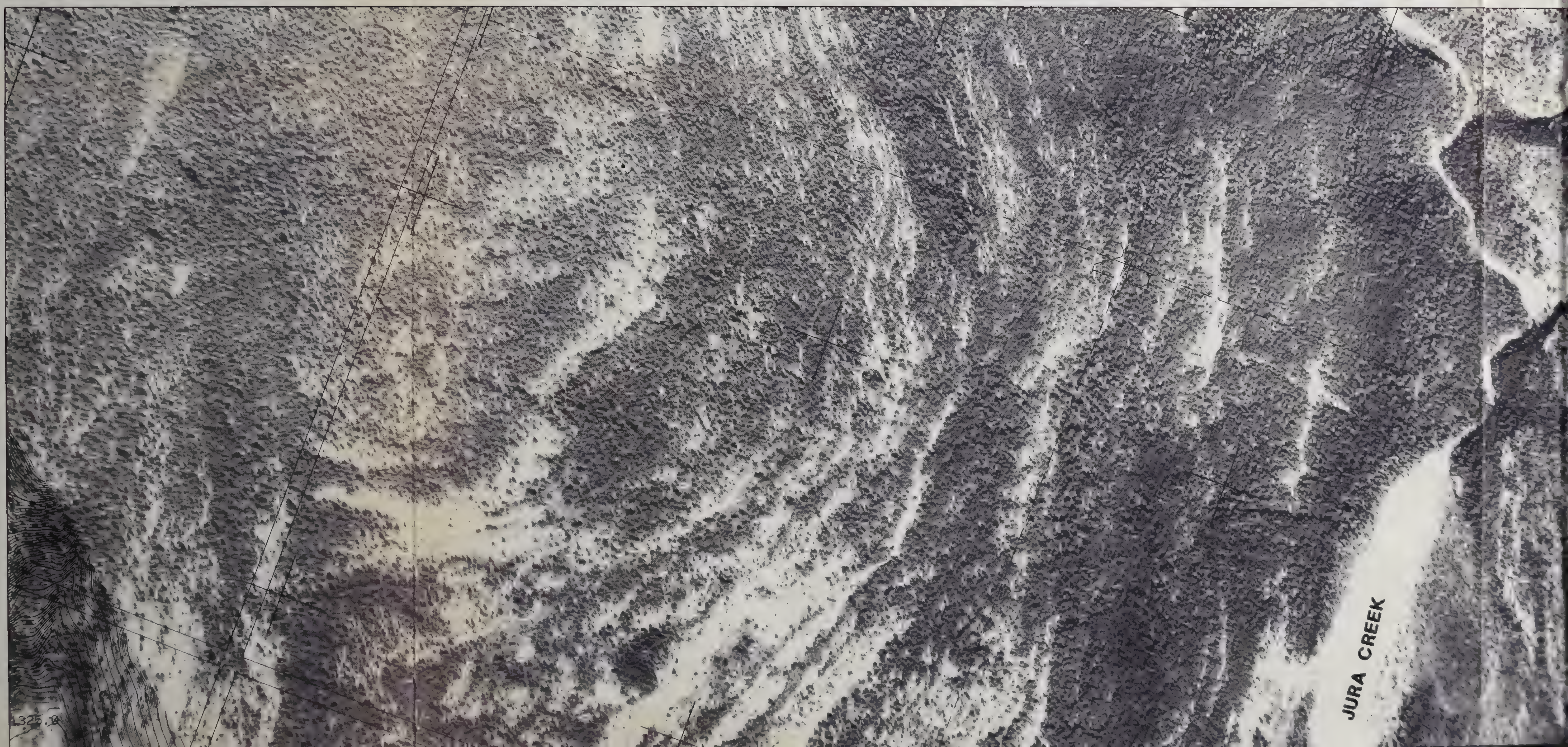
FLOOD FREQUENCY MAP SHEET 2 OF 3

SCALE: 1:5000

ACRES PROJECT NO. **P11426.00**

DRAWING NO.: 11426-05

REV A


JURA CREEK

KANANASKIS
JURA CREEK
1320.0
1315.0

Flood Frequency Map

Notes:

1) Man-made inlet channel replaced by dyke inlet structure with a 1.2 m diameter gated corrugated steel pipe and a 0.6 m non-gated elliptical corrugated steel pipe.

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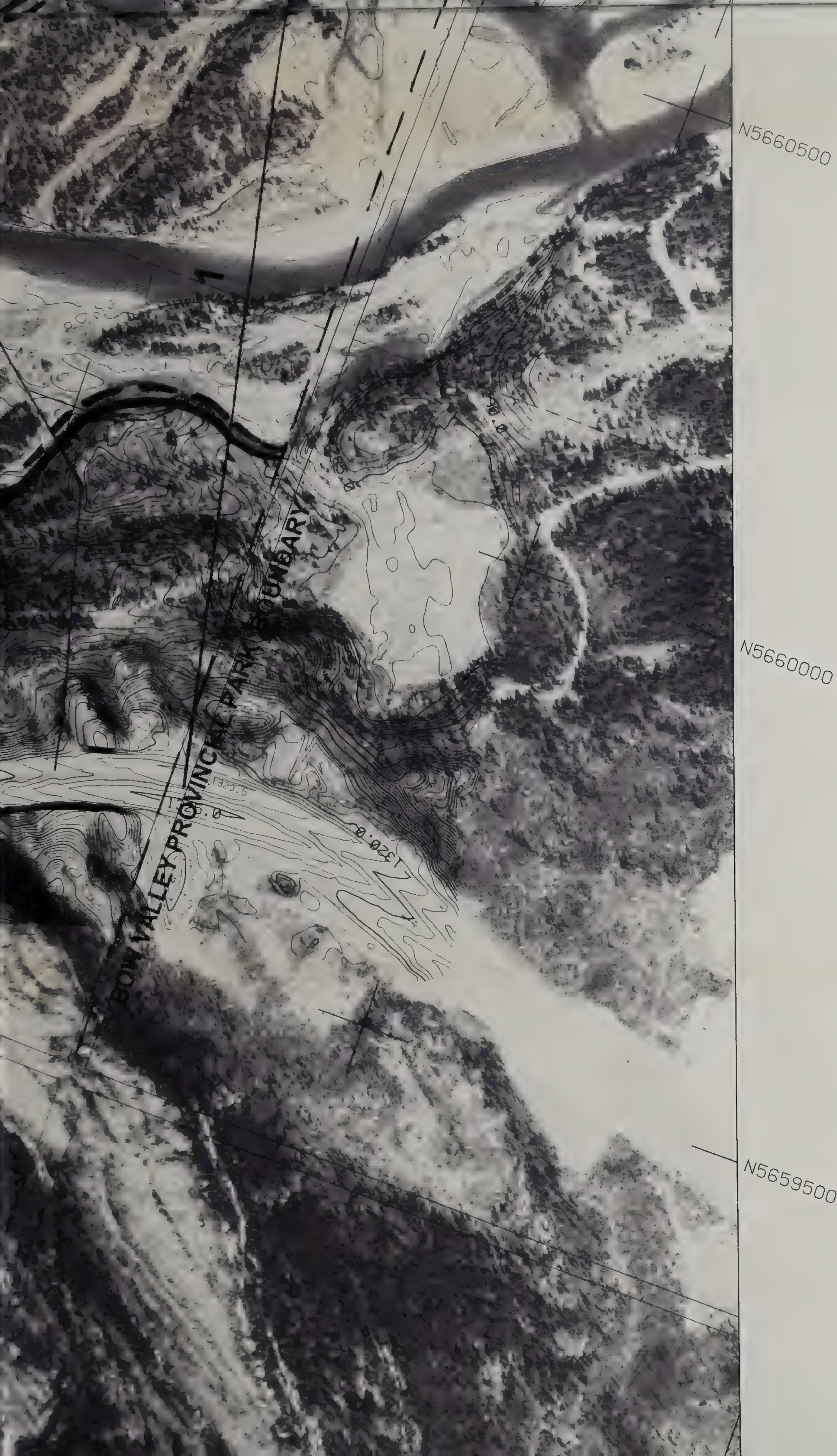
6	1286.6	1286.1
7	1287.3	1286.8
8	1287.8	1287.4


EXSHAW CREEK
EXSHAW
HIGHWAY 1A
CANADIAN PACIFIC RAILWAY
EXSHAW INDUSTRIAL PARK
SEWAGE TREATMENT PLANT
BOW RIVER
LAC DES ARCS
E 15
E 10
E 5
E 1
11
10
9
8
6


LIME PLANT
TRANS-CANADA HIGHWAY
BOW RIVER
BOW VALLEY PROVINCIAL PARK BOUNDARY
1
2
3
1290.0
1295.0
1320.0



8	1287.8	1287.4
9	1288.6	1288.3
10	1290.6	1290.0
11	1291.0	1290.6
12	1292.9	1292.0
13	1293.4	1292.4
14	1293.5	1292.4
15	1293.5	1292.6
16	1293.6	1292.7
17	1293.6	1292.7
18	1293.7	1292.8
19	1293.8	1292.9
20	1293.8	1292.9
21	1294.1	1293.2

Legend:

Flood risk limit of the 100 year flood

Flood risk limit of the 10 year flood

5 Cross section number and location

E-81015.32

E-80500

E-80000

E-79500

Canada-Alberta
FLOOD
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Environment Canada

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ENVIRONMENTAL PROTECTION

CADD FILE 11426-TB.DWG LAST PLOT DATE: DEC 11/95

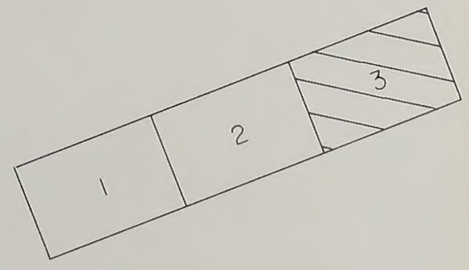
E-79500

E-79000

E-78500

E-78000

E-77500



SCALE 1:5 000

metres 0 100 200 300 400 500 600

feet 0 100 500 1,000 1,500 2,

Projection: 3° Transverse Mercator, Scale factor 0.9999 at Reference Meridian 114°

Contour interval: 1 METRE Where the ground is fully obscured, contours are dashed.

Where the index contours are less than 5 mm apart, intermediate contours have been dropped

Elevations: in metres above mean sea level, North American Datum, 1927

metre contour

metre index contour

Depression contou

.1082.6 Spot height in metr

N5659000

N5658586.30

E-77500

E-77256.52

Legend:

- Flood risk limit of the 100 year flood
- Flood risk limit of the 10 year flood
- 5 — Cross section number and location
- Flow direction
- Dyke center line

SCALE 1:5 000

100 200 300 400 500 600 metres

100 500 1,000 1,500 2,000 feet

ection: 3° Transverse Mercator, Scale factor 0.9999 at Reference Meridian 114°

our interval: 1 METRE Where the ground is fully obscured, contours are dashed.

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metre contour

metre index contour

Depression contour

.1082.6 Spot height in metres

BIGHORN /
BOW RIVER

Orthophoto MAY 1993
Contours MAY 1993

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES

ALBERTA ENVIRONMENTAL PROTECTION

BOW RIVER - M.D. OF BIGHORN

FLOOD RISK MAPPING STUDY

ACRES INTERNATIONAL LIMITED

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DRAWING
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PROJECT MANAGER
D. ROBERTS

FLOOD FREQUENCY MAP
SHEET 3 OF 3

SCALE: 1:5000

ACRES PROJECT NO. **P11426.00**

DRAWING NO.: 11426-06

REV. A